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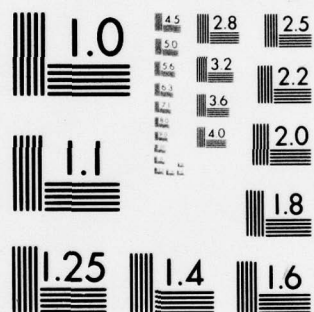
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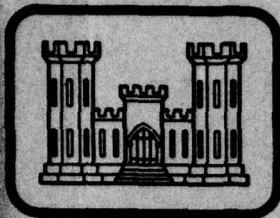
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TECHNICAL REPORT D-77-38

HABITAT DEVELOPMENT FIELD INVESTIGATIONS MILLER SANDS MARSH AND UPLAND HABITAT DEVELOPMENT SITE, COLUMBIA RIVER, OREGON

SUMMARY REPORT

by

Ellis J. Clairain, Jr., Richard A. Cole, Robert J. Diaz
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Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

December 1978
Final Report

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U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI 39180-0631
SUMMARY REPORT
DEC 1978

**HABITAT DEVELOPMENT FIELD INVESTIGATIONS, MILLER SANDS
MARSH AND UPLAND HABITAT DEVELOPMENT
SITE, COLUMBIA RIVER, OREGON**

- Appendix A: Inventory and Assessment of Predisposal Physical and Chemical Conditions**
- Appendix B: Inventory and Assessment of Predisposal and Postdisposal Aquatic Habitats**
- Appendix C: Inventory and Assessment of Prepropagation Terrestrial Resources on Dredged Material**
- Appendix D: Propagation of Vascular Plants on Dredged Material**
- Appendix E: Postpropagation Assessment of Botanical and Soil Resources on Dredged Material**
- Appendix F: Postpropagation Assessment of Wildlife Resources on Dredged Material**

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VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESEV

15 March 1979

SUBJECT: Transmittal of Technical Report D-77-38

TO: All Report Recipients

1. The technical report transmitted herewith contains results of one of a series of research efforts (work units) undertaken as a part of the Habitat Development Project (HDP) of the Corps of Engineers' Dredged Material Research Program (DMRP). The HDP had as one of its objectives the testing and evaluation of habitat development as an alternative method of dredged material disposal.

2. Marsh and upland habitat development using dredged material was investigated by the HDP under both laboratory and field conditions. This report, "Habitat Development Field Investigations, Miller Sands Marsh and Upland Habitat Development Site, Columbia River, Oregon; Summary Report" (Work Unit 4B05M), summarizes the activities that occurred during marsh and upland habitat development studies in Clatsop County, Oregon, between 1975 and 1977. A general discussion of the engineering and biological aspects of the research is presented. The reader is referred to Appendices A through F to this report for more detailed discussions.

3. A total of nine marsh development sites were selected and designed by the HDP at various locations throughout the United States. Six sites were subsequently constructed. Those, in addition to Miller Sands, include: Windmill Point on the James River, Virginia (4A11); Buttermilk Sound, Atlantic Intracoastal Waterway, Georgia (4A12); Apalachicola Bay, Apalachicola, Florida (4A19); Bolivar Peninsula, Galveston Bay, Texas (4A13); and Salt Pond No. 3, San Francisco Bay, California (4A18). Detailed design for marsh restoration at Dyke Marsh on the Potomac River (4A17) was completed, but project construction was delayed in the coordination process. Marsh development at Branford Harbor, Connecticut (4A10), and Grays Harbor, Washington (4A14), was terminated because of local opposition and engineering infeasibility, respectively. Upland habitat was developed at two sites in addition to Miller Sands: Bolivar Peninsula and Nott Island, Connecticut River, Connecticut (4B04).

4. Evaluated together, the field site studies plus ancillary field and laboratory evaluations conducted in the HDP establish and define the range of conditions under which marsh and upland habitat development is feasible. Data presented in the research reports prepared for this task

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15 March 1979

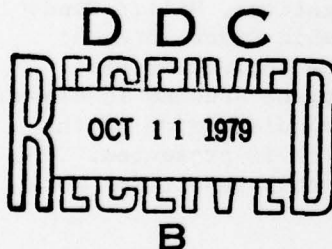
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will be synthesized in the technical reports entitled "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations" (2A08), "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation" (4A24), and "Upland Habitat Development with Dredged Material: Engineering and Plant Propagation" (4B09).

John L. Cannon

JOHN L. CANNON

Colonel, Corps of Engineers
Commander and Director



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18. SUPPLEMENTARY NOTES Appendices A through D were prepared as separate reports and are enclosed in a separate envelope attached to the back cover of this report. Appendices E and F were published separately.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Columbia River Habitat development Vascular plants Dredged material Habitats Vegetation establishment Field investigations Marsh development Waste disposal sites Fish Miller Sands Island Wildlife		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A two and one-half year field investigation was conducted at Miller Sands Island, a tidal freshwater, dredged material disposal site in the Columbia River, Oregon. The field study was conducted to test the feasibility and the impact of developing marsh and upland habitats on dredged material. Summarized within this report are baseline information obtained before habitat development operations and results of post-development operational studies. (Continued)		

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20. ABSTRACT (Continued)

Selected plant species were planted on both intertidal and upland areas of Miller Sands Island. Data were collected to determine plant survival and performance in response to tidal inundation, varied fertilizer treatments, wildlife utilization, planting methods, and plant invasion. Data were also collected to document changes in the aquatic and terrestrial animal communities before, during, and after plant propagation activities.

Plantings were generally successful in both the intertidal and upland areas. Growth and survival of tufted hairgrass (*Deschampsia caespitosa*) and slough sedge (*Carex obnupta*), the two species planted in the intertidal monotypic test plots, showed significant effects of elevation with almost all surviving plants occurring at elevations greater than 67 cm above mean lower low water. Biomass production of tufted hairgrass plantings was greater than the slough sedge plantings and compared well to native stands of tufted hairgrass. Results obtained from planting European beachgrass (*Ammophila arenaria*) on the upland area of the sand spit correlated well with similar findings obtained by other researchers who used this species to stabilize sand dunes along the Pacific Coast. Species planted in the upland meadows, though initially successful, appeared to be poorly adapted to maintain good growth in the nutrient-poor, sandy dredged material substrate.

The intertidal plantings provided habitat for aquatic and terrestrial animal communities but did not greatly improve or damage animal populations. Fish and benthic abundance in the planted areas was not significantly different from other areas sampled in the intertidal areas. Initially there were fewer bird species in the planted marsh than in reference areas; however, as the marsh grew, a trend developed near the end of the study which indicated that the number of species using the planted areas eventually would resemble that in natural areas. The planted upland areas were used by waterfowl more than upland reference areas although the number of avian species was less. Canada geese (*Branta canadensis*) and snow geese (*Chen caerulescens*) preferred the upland meadow planted in barley (*Hordeum vulgare*) for feeding. Mallards (*Anas platyrhynchos*) preferred the upland meadow planted in reed canarygrass (*Phalaris arundinacea*), red fescue (*Festuca rubra*), and hairy vetch (*Vicia villosa*) for nesting more than other upland meadows but less than tree-shrub habitats.

After about one year of development, planted habitats at the field site are expanding and are expected to provide additional future wildlife habitat as plant succession continues.

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PREFACE

This report presents a summary of studies conducted at Miller Sands Island, a tidal freshwater, dredged material disposal site in the Columbia River, Oregon. Studies were conducted from March 1975 to August 1977 to determine the feasibility of developing productive aquatic and terrestrial wildlife habitat on dredged material and to determine if development of wildlife habitat is a viable alternative to other dredged material disposal options.

The Habitat Development Project (HDP) studies at the Miller Sands Marsh and Upland Habitat Development Site were conducted as part of the Dredged Material Research Program (DMRP), a nationwide research program sponsored by the Office, Chief of Engineers. The DMRP was planned and managed by the Environmental Laboratory (EL) of the Waterways Experiment Station (WES), Vicksburg, Mississippi.

This report was written primarily by the staff of the Natural Resources Development Branch, Environmental Resources Division of EL. Overall coordination and technical editorial responsibility for the report was by Mr. Ellis J. Clairain, Jr. Ms. Dorothy P. Booth also provided significant editorial review. Individual sections of the report were written by Mr. Alfred W. Ford, engineering and construction operations; Dr. Robert T. Huffman, botany; Dr. B. R. Wells, soils; Mr. Ellis J. Clairain, Jr., and Dr. Robert J. Diaz, aquatic biology; and Ms. L. Jean Hunt and Dr. Richard A. Cole, wildlife. Two other individuals, Mr. E. Paul Peloquin of the U. S. Army Engineer District, Walla Walla, Washington, and Dr. J. Scott Boyce of the U. S. Geological Survey in Reston, Virginia, were formerly at WES and provided significant input into the development of the study plan.

Appendices to this summary report represent individual studies which provided the data base upon which this summary report was developed. The individual studies and contractors are appended as follows:

Appendix A: Inventory and Assessment of Predisposal Physical and Chemical Conditions - Oregon State University, Corvallis, Oregon

- Appendix B: Inventory and Assessment of Predisposal and Post-disposal Aquatic Habitats - National Marine Fisheries Service, Seattle, Washington
- Appendix C: Inventory and Assessment of Prepropagation Terrestrial Resources on Dredged Material - Woodward-Clyde Consultants, Portland, Oregon
- Appendix D: Propagation of Vascular Plants on Dredged Material - Wave Beach Grass Nursery, Florence, Oregon
- Appendix E: Postpropagation Assessment of Botanical and Soil Resources on Dredged Material - Washington State University, Pullman, Washington
- Appendix F: Postpropagation Assessment of Wildlife Resources on Dredged Material - Oregon State University, Corvallis, Oregon

The HDP was under the supervision of Dr. Hanley K. Smith, Project Manager. General supervision was provided by Dr. C. J. Kirby, Chief, Environmental Resources Division, and by Dr. John Harrison, Chief, EL.

Commanders and Directors of WES during the period of this study were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Mr. F. R. Brown was Technical Director.

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APPENDIX C: INVENTORY AND ASSESSMENT OF PREPROPAGATION TERRESTRIAL
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APPENDIX D: PROPAGATION OF VASCULAR PLANTS ON DREDGED MATERIAL

APPENDIX E: POSTPROPAGATION ASSESSMENT OF BOTANICAL AND SOIL
RESOURCES ON DREDGED MATERIAL

APPENDIX F: POSTPROPAGATION ASSESSMENT OF WILDLIFE RESOURCES ON
DREDGED MATERIAL

NOTE: ~~Appendices A through D were reproduced on microfiche and
are enclosed in an envelope attached inside the back
cover of this report.~~ Appendices E and F were published
separately.

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Conversion Factors, U. S. Customary to Metric (SI) and Metric (SI)
to U. S. Customary Units of Measurement

Units of measurement used in this report can be converted as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
<u>U. S. Customary to Metric (SI)</u>		
acres	4046.856	square metres
acres	0.405	hectares
pounds (mass)	0.454	kilograms
tons	0.907	metric tons
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
<u>Metric (SI) to U. S. Customary</u>		
centimetres	0.394	inches
metres	3.281	feet
kilometres	0.614	miles (U. S. Statute)
square metres	10.764	square feet
hectares	2.471	acres
grams	0.002	pounds (mass)
Celsius degrees	9/5	Fahrenheit degrees**

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

** To obtain Fahrenheit (F) temperature readings from Celsius (C) readings, use: $F = (9/5)(C + 32)$.

HABITAT DEVELOPMENT FIELD INVESTIGATIONS,
MILLER SANDS MARSH AND UPLAND HABITAT
DEVELOPMENT SITE, COLUMBIA RIVER, OREGON;
SUMMARY REPORT

PART I: INTRODUCTION

1. The removal of sediments from navigable waters in the United States has been the responsibility of the U. S. Army Corps of Engineers since Congressional authorization in 1824 (U. S. Army, Office, Chief of Engineers 1969). The magnitude of this responsibility has been immense in recent years with annual dredging necessary at about 500 harbor projects and thousands of kilometres of waterways (Boyd et al. 1972). Annual maintenance dredging requires disposal of about $229,366,500 \text{ m}^3$ of material and an additional $61,164,400 \text{ m}^3$ are dredged for new work annually (Boyd et al. 1972). This quantity of dredged material is equivalent to sediment one metre thick over an area greater than 290 km^2 .

2. The above figures illustrate the national scope of Corps of Engineers dredging activities with most dredging occurring in coastal areas, primarily the Gulf and South Atlantic coastal regions. However, one of the most intensively dredged areas along the Pacific Coast is the Columbia River where over $7,263,000 \text{ m}^3$ of material were dredged annually during the period from 1971-1973 (U. S. Army Engineer District, Portland 1975). Unlike many areas along the Gulf and Atlantic Coasts where dredged material often consists of fine-textured sediments contaminated with industrial and municipal wastes, over 75 percent of the dredged material in the Portland District of the U. S. Army Corps of Engineers consists of relatively clean sand, gravel, or shell (Boyd et al. 1972). These relatively clean sandy sediments of the Columbia River allow the Portland District a wide variety of alternatives for the disposal of dredged material. The large quantities of dredged material create enormous problems as to where, when, and how to dispose of this material in an economically and environmentally responsible manner. Enhancement of

the habitat value of a dredged material disposal site is a viable option in many situations. The purpose of this study was to test methodologies for habitat development at Miller Sands, an actively used dredged material disposal island at river kilometre 39 in the Columbia River, Oregon.

3. The Miller Sands Marsh and Upland Habitat Development Site represents one of seven experimental projects in the contiguous United States constructed to examine the feasibility of using dredged material for development of productive fish and wildlife habitat. Summarized within this report is the progress of site development and field observations before and after dredged material disposal in July 1975.

4. Specific research objectives addressed at the Miller Sands site included:

- a. Documentation of the planning, design, construction, and subsequent physical changes in the substrate and engineered structures used for habitat development.
- b. Documentation and evaluation of the planting and cultural practices used for habitat development.
- c. Investigation of relationships between plant productivity and substrate characteristics for selected plant species propagated on the dredged material.
- d. Documentation of animal use of the dredged material and plant community development on the site.

PART II: SITE CHARACTERIZATION

Site Selection Criteria

5. The selection of Miller Sands for study of habitat development activities was made after establishment of several criteria for site selection and after examination of several potential locations. The following criteria were established and were most closely satisfied by conditions at Miller Sands:

- a. The site should be representative of dredged material disposal areas in the Pacific Northwest.
- b. It should provide a good representation of a tidally influenced freshwater marsh and upland area.
- c. The dredged material used as a substrate should be clean sandy material since sand is the predominant dredged material in the Pacific Northwest.
- d. The site should be located in a relatively mild erosive energy regime.
- e. Development of the site should be accomplished in conjunction with an authorized dredging project and should be compatible with the time frame of the Dredged Material Research Program.

Corps of Engineers Setting

6. The Miller Sands site is associated with the Columbia River channel dredging project. This project was first authorized in 1877 and was last modified in 1972. It provided for maintenance of a shipping channel 12.2 m deep and 182.9 m wide from near the river's mouth to river kilometre 169.8 and a channel 10.7 m deep and 152.4 m wide to river kilometre 171.4. This project also provided for the maintenance of one turning basin at Astoria, Oregon, one at Longview, Washington, two at Vancouver, Washington, two auxiliary channels from the Columbia River to St. Helens and Rainier, and side channels at Cathlamet and Longview, Washington.

7. Over 85 disposal sites, ranging in size from 2.4 to 453.2 ha, are authorized for the Columbia River dredging project. The 453.2-ha

site is, however, a relatively large area since the second largest site is only 218.1 ha. The Miller Sands site is 94.7 ha and only 19 of the disposal sites are larger than Miller Sands.

8. The dredged material placed at the Miller Sands site is obtained from the stream reach between river kilometres 35.4 and 40.2. The average annual volume of material dredged from this reach of the river is about 500,000 m³, part of which is disposed on Miller Sands by hydraulic dredge.

Site Description

Geographical

9. Miller Sands is a horseshoe-shaped island located on the Columbia River, about 4 km upriver from Astoria, Oregon (Figure 1). It is one of many islands located within the Lewis and Clark National Wildlife Refuge and is owned partially by the state of Oregon and partially by Clatsop County, Oregon.

10. The island was first formed in 1932 from material dredged from the adjacent navigation channel. Subsequent dredging and deposition resulted in the present 94.7-ha (U. S. Army Engineer District, Portland 1975) island configuration illustrated in Figure 2.

Meteorological

11. The climate of the Lower Columbia River is marine, Pacific-Northwest maritime, characterized by foggy, wet winters and dry summers. The mean annual precipitation reported for Astoria, Oregon, the nearest recording station to Miller Sands, is 168.5 cm (National Oceanic and Atmospheric Administration 1976). About one to two percent of the annual precipitation is reported as snowfall (U. S. Army Engineer District, Portland 1975).

12. Average maximum summer temperatures range from 21 to 27°C and average minimum temperatures range from 7 to 13°C. Average maximum winter temperatures vary from 2 to 7°C with the average minimum ranging from -4 to 2°C. Summer temperatures occasionally rise to 38°C or dip below 0°C and winter temperatures of 21°C and -23°C have been reported (U. S. Army Engineer District, Portland 1975).

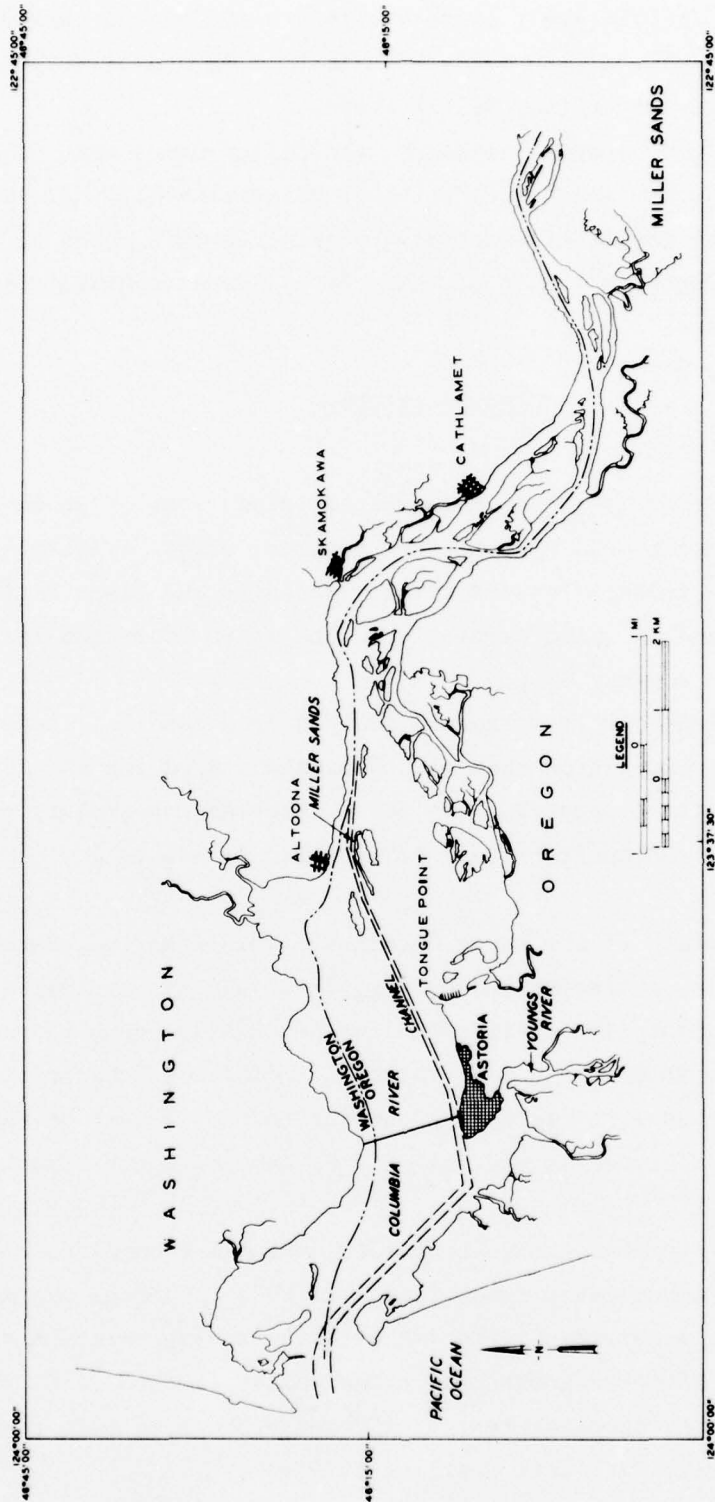


Figure 1. Geographic location of the Miller Sands marsh and upland habitat development site, Columbia River, Oregon

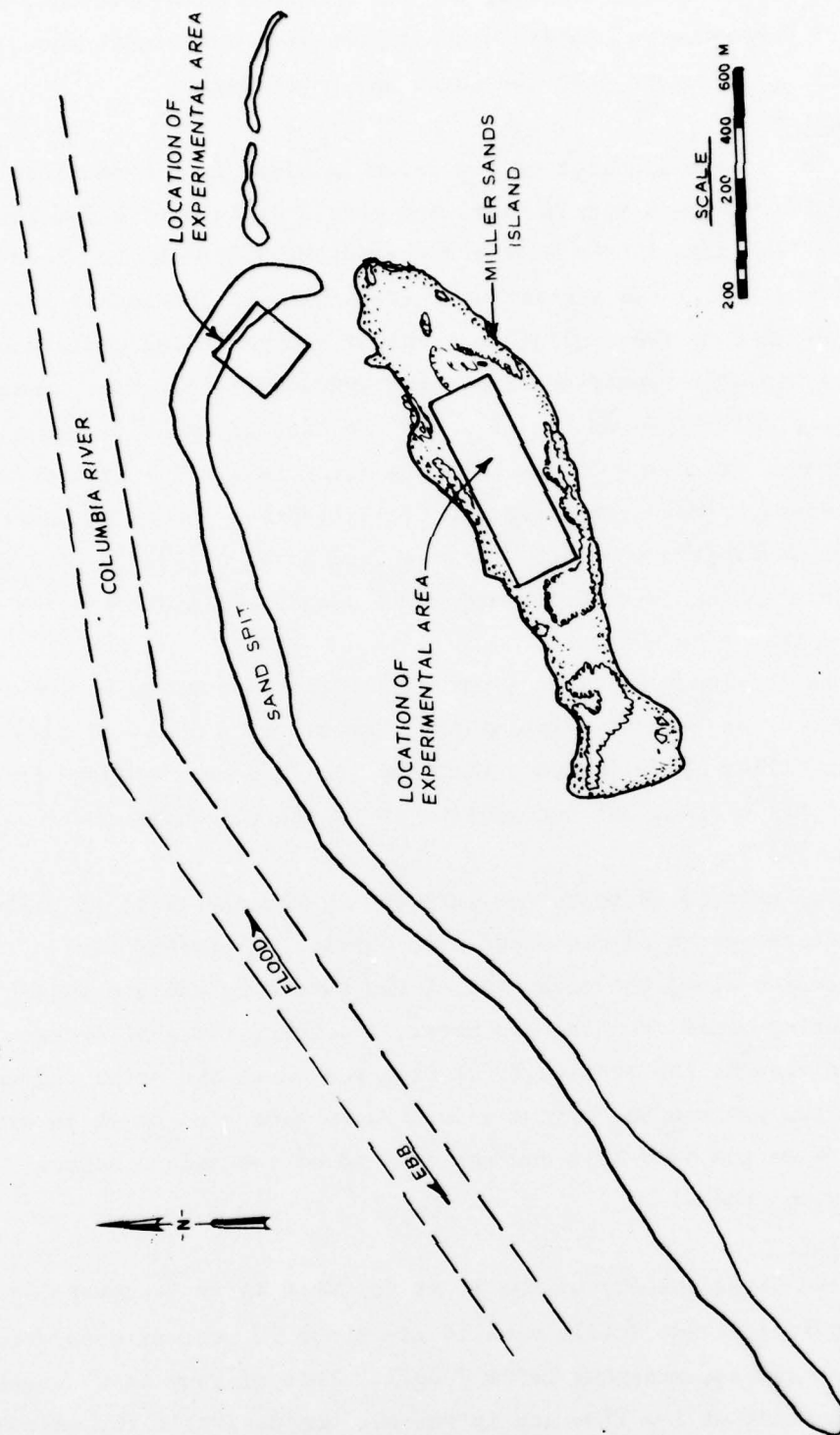


Figure 2. Miller Sands Island and sand spit after dredged material disposal in July 1975

13. Most air masses crossing the Miller Sands area originate over the ocean. Strong winds usually occur in the fall and winter when intense storms move inland from the south and southwest.

Hydrological

14. The stream gradient of the Columbia River from Bonneville Dam to the Pacific Ocean is nearly flat, and stream width during low flow varies from less than 1.6 km wide above river kilometre 50 to about 14.5 km wide at the river kilometre 37 (Cutshall and Johnson 1977).

15. Because of the negligible gradient, asymmetrical semidiurnal tides and freshwater runoff are important hydrologic features. Mean tidal range at Miller Sands is 1.9 m and the diurnal range is 2.3 m. The mean annual discharge of the Columbia River is $7,219 \text{ m}^3/\text{sec}$ or about twice the annual freshwater discharge from all other rivers in California, Oregon, and Washington combined (Cutshall and Johnson 1977). Peak discharge occurs during late spring and early summer and minimum flows occur in September and October.

16. In the lower Columbia River, discharge appears to be the controlling factor on lateral circulation. Measurements obtained downstream from Miller Sands indicate that when daily mean discharge is less than $4,671 \text{ m}^3/\text{sec}$, net circulation is counterclockwise (Cutshall and Johnson 1977).

17. Two major erosive forces influencing the stability of Miller Sands substrates are wind waves and ship wakes. The former cause greatest erosion along the cove side of the sand spit and are most damaging during winds from the southwest. However, the shallowness of the cove reduces the erosive force of these waves and helps reduce erosion in the eastern end of the cove. Waves generated by ships are most erosive on the sand spit and western end of the island nearest the navigation channel.

Water quality

18. The water quality of the lower Columbia River is generally good. Dissolved oxygen levels usually are above 90 percent saturation with only occasional minimums below 7 mg/l. This minimum level usually occurs in periods of low flow and is the minimum desirable for salmonid

migrations. Background levels of the biological oxygen demand are generally about 1 mg/l; the pH ranges from 6.4 to 8.4; and dissolved solids range from 75 to 112 mg/l. The suspended sediment concentration in the lower Columbia River is usually low, averaging 100 mg/l. Mean annual turbidity is approximately 10 to 15 Jackson turbidity units. Ocean water intrusion seldom penetrates farther upstream than river kilometre 32.

19. The principal water quality problems in the lower Columbia River are temperature fluctuations and supersaturated levels of dissolved nitrogen. Water temperatures in August usually exceed desirable levels for salmonids. This peak usually coincides with the period of least abundance and activity of anadromous fish. Supersaturation of dissolved nitrogen above 110 percent may cause damaging cases of gas bubble disease in stressed salmonids. Spilling by dams in spring and early summer is the principal cause of supersaturation. Supersaturated levels of nitrogen as high as 140 percent have been reported in the Columbia River from Grand Coulee Dam to the mouth (U. S. Army Engineer District, Portland 1975).

Biological

20. Benthic communities in the brackish and freshwater areas of the Columbia River estuary are dominated by amphipods, oligochaetes, and the Asiatic clam (*Corbicula fluminea*). Benthic and plankton sampling in August through October 1973 (Sanborn 1975) at river kilometre 29 indicated the presence of two marine species of amphipods, *Anisogammarus confervicolus* and *Eohaustorius* sp., and one freshwater species, *Corophium salmonis*. Other studies (Higley and Holton 1975; Higley et al. 1976) also indicated the dominance of *Corophium salmonis* in freshwater areas similar to those at Miller Sands. The zooplankton community at river kilometre 29 was composed primarily of freshwater species although some marine forms such as *Eurytemora hirundoides*, polychaete larvae, and barnacle larvae were also present.

21. Anadromous fish include salmon (*Onchorhynchus* spp), American shad (*Alosa sapidissima*), smelt (*Osmeridae*), and Pacific lamprey (*Entosphenus tridentatus*). Freshwater species that migrate

within the river between feeding areas and spawning grounds include sturgeon (*Acipenser spp.*) and trout (*Salmo spp.*). Salmon, sturgeon, and American shad are important commercially and for recreation. Spawning of salmonids is confined to tributaries and little or none occurs in the lower Columbia River. About 900,000 adult salmonids move upstream through the lower Columbia River and into its tributaries each year: 50 percent of these are chinook salmon (*O. tshawytscha*); 20 percent are coho salmon (*O. kisutch*); and 10 percent are sockeye salmon (*O. nerka*). The peak downstream movement of young salmonids occurs in spring and fall. About one million American shad and 200,000 Pacific lamprey also pass through the lower Columbia River during peak migration periods for these species (U. S. Army Engineer District, Portland 1975).

22. The intertidal marshlands of Miller Sands consist primarily of mudflats and marshes dominated by common spike-rush (*Eleocharis palustris*), Lyngby's sedge (*Carex lyngbyei*), and tufted hairgrass (*Deschampsia caespitosa*). On the more protected sides of the island, the intertidal zone is usually separated from adjacent upland areas by a fringe of willows (*Salix spp.*) and reed canarygrass (*Phalaris arundinacea*).

23. The upland areas of the island are dominated by common scouring-rush (*Equisetum hyemale*), common velvetgrass (*Holcus lanatus*), and dense patches of mosses (*Polytrichum juniperinum* and *Rhacomitrium heterostrichum*). Isolated Sitka spruce trees (*Picea sitchensis*) and patches of the introduced Scot's broom (*Cytisus scoparius*) are also found in the open grassland meadow. Dense stands of black cottonwood (*Populus trichocarpa*) and red alder (*Alnus rubra*) occur over the remaining upland portions of the island on more mesic, less well-drained substrates.

24. The lower Columbia River is in the path of the Pacific flyway for migratory waterfowl. Many waterfowl utilize the river from Tongue Point to Vancouver-Portland in the late fall and winter. About 76 species of birds have been seen at Miller Sands during spring, but transients accounted for most of the species observed (Woodward-Clyde

Consultants 1978). Nesting species on the lower Columbia River area included waterfowl, killdeer (*Charadrius vociferus*), song sparrows (*Melospiza melodia*), white-crowned sparrows (*Zonotrichia leucophrys*), and common crows (*Corvus branchyrhynchos*).

25. The floodplain of the lower Columbia River also supports several mammalian species. Resident mammals in the island-marsh complex at Miller Sands include nutria (*Myocastor coypus*), Norway rats (*Rattus norvegicus*), Townsend's voles (*Microtus townsendii*), and muskrat (*Ondatra zibethicus*). The sand spit, immediately adjacent to the island, is occasionally used by harbor seals (*Phoca vitulina*) and transient river otters (*Lutra canadensis*).

Cultural

26. The human population in the region around the lower Columbia River has grown substantially (2.12 percent annually) during the last decade (U. S. Army Engineer District, Portland 1975). This growth has occurred mostly in urban areas and apparently is correlated with the economic expansion associated with rapid industrialization. Water-related commerce has burgeoned along with associated production, transportation, and supportive services. Commercial fishing is also important economically with the catch in the Astoria area in 1974 valued at \$13.7 million (U. S. Army Engineer District, Portland 1975). Consumptive uses of the lower Columbia River water are primarily devoted to pulp and papermill industries, with some consumption by other industries and a small amount of irrigation. Most domestic water consumption comes from wells and tributaries and not the Columbia River itself (U. S. Army Engineer District, Portland 1975).

PART III: ENGINEERING AND CONSTRUCTION OPERATIONS

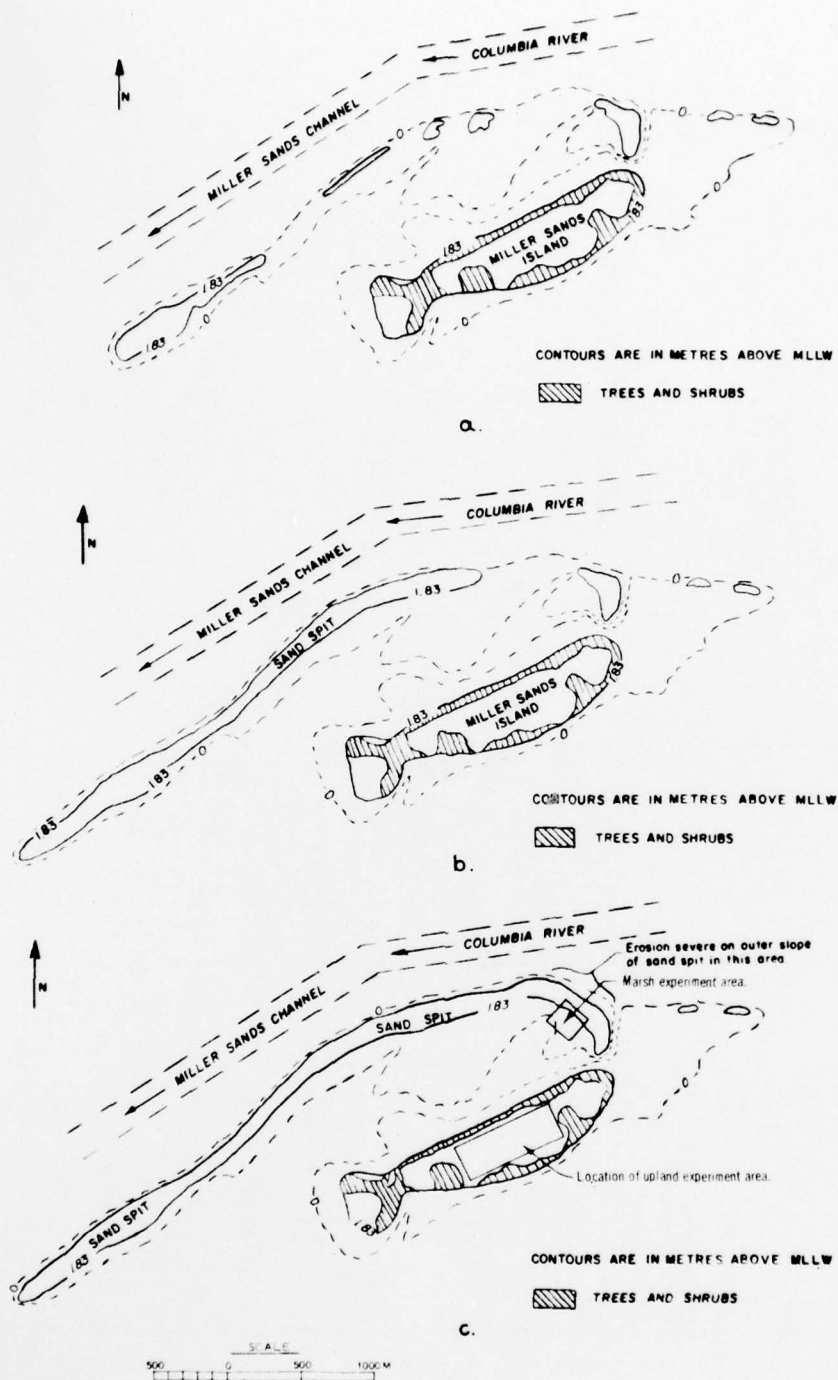
Site Development

27. Miller Sands Island was first formed from dredged material hydraulically deposited in 1932. Since that time dredged material has been deposited on the island about every 2 to 2-1/2 years.

28. Habitat development at Miller Sands began in mid-1974 when the U. S. Army Engineer District, Portland, in conjunction with the U. S. Fish and Wildlife Service and other agencies, planned to create a protected waterfowl habitat area adjacent to Miller Sands Island. To develop this area, 612,085 m³ of dredged material were deposited along the channel side of Miller Sands between 24 June and 27 July 1974. This material formed a long, narrow sand spit. Development of the sand spit by sequential disposal operations is illustrated in Figure 3.

29. Field research for the Habitat Development Project was initiated at Miller Sands following the dredged material disposal operation in July 1974. In October 1974, the Portland District surveyed the existing sand spit and cove to determine how much more material would be required to complete the spit and to determine the general composition of the material previously deposited. The quantity and distribution of material deposited during the 1974 dredging operation were determined from soil borings. Boring locations, boring logs, and a generalized surface and subsurface profile between borings are presented in Figure 4. Analysis of the samples indicated that the dredged material consisted mainly of brown sand overlying grey silty sand and that 90 percent of the particles were larger than 0.1 mm in diameter.

30. Dredged material disposal operations were continued in mid-July 1975 when 236,730 m³ of material were placed on the sand spit and inside the cove between the spit and the island. The sandy dredged material was used to complete the formation of the sand spit and to provide sufficient substrate material within the cove for the planned marsh establishment area. Disposal on the sand spit in July 1975 resulted in the present configuration (Figure 3c). The crest of the sand spit was raised during



the 1975 disposal operation to an elevation ranging between 3.0 and 4.5 m above mean lower low water (MLLW).

31. An area approximately five hectares in size was graded with a bulldozer to a one-percent slope ranging from 2.1 m above MLLW near the crest of the sand spit to MLLW toward the cove. After grading, an area 214 m on a side was subdivided into 270 plots 11.9 m by 14.2 m each (Figure 5). After delineating the location of each of the 270 plots and establishing a grid identification system, the Portland District surveyed the area and determined the elevation of each plot corner stake.

32. Site development on the main island included the layout for three large meadows (242 m by 248 m) and three smaller meadows (70 m by 117 m) of monotypic plots (Figure 6).

Protective Structures

33. The lower Columbia River is an area periodically subjected to considerable wind and ship wave energies. However, the shallow conditions developed within the cove area provided considerable protection by dissipating much of the wave energies. Protection of the marsh plantings against windblown sand from the sand spit was provided by planted vegetation and by two wood lath fences about 1 m high and 213 m long. These fences were constructed along the northeast border of the experimental area and, in conjunction with the planted vegetation mixture, provided satisfactory protection for the marsh monotypic plantings.

Maintenance

34. After initial site development activities in 1975, additional engineering assistance was required from the Portland District to provide periodic elevation measurements within the planted intertidal area. These measurements were used to determine changes in sediment deposition and erosion and to provide information necessary to assess the influence of inundation on vegetation distribution and productivity. These surveys were conducted in November 1976 and in April, July, and October 1977.

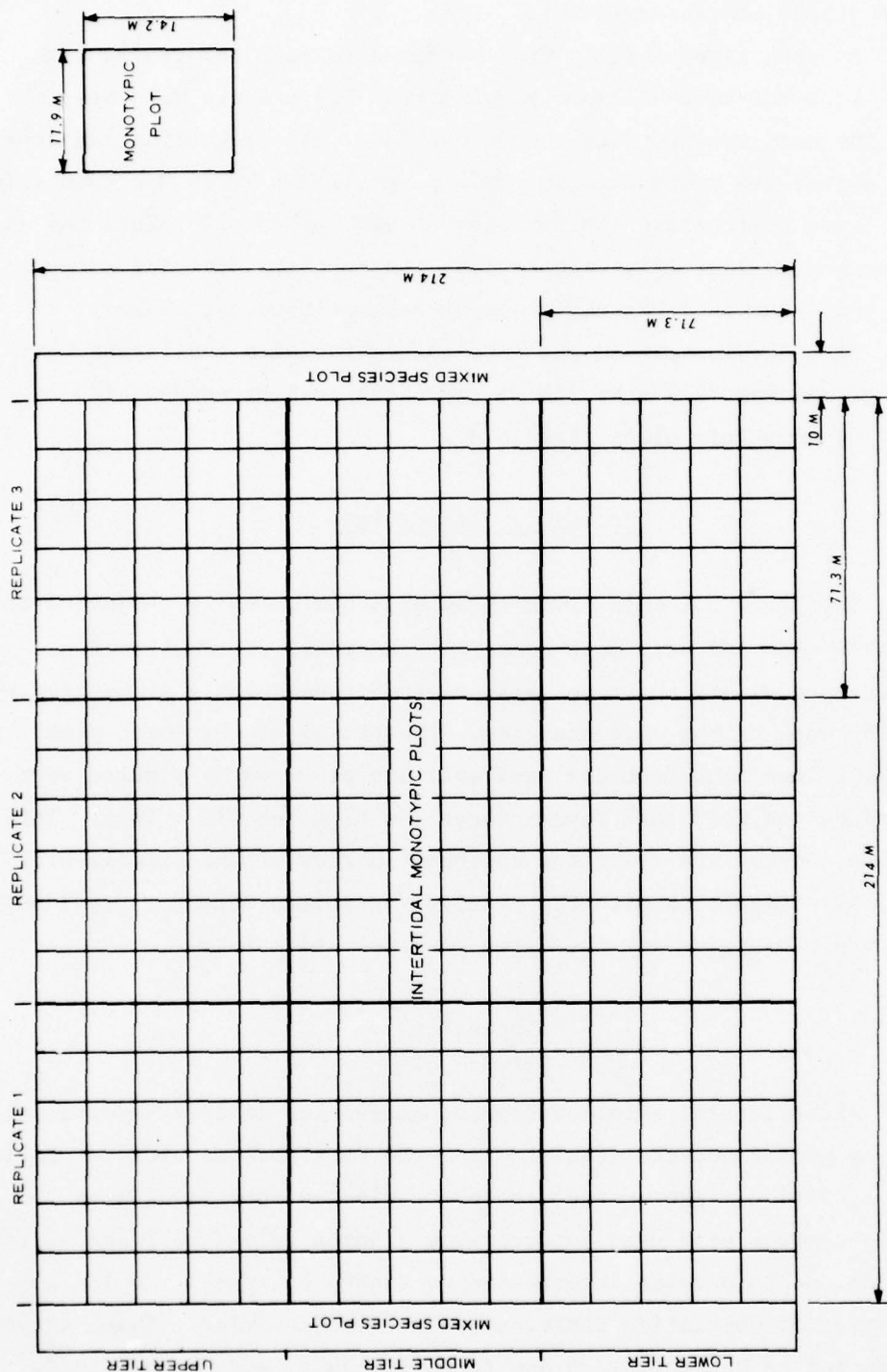


Figure 5. Layout design of intertidal plantings indicating relationship of monotypic plots and mixed species plots

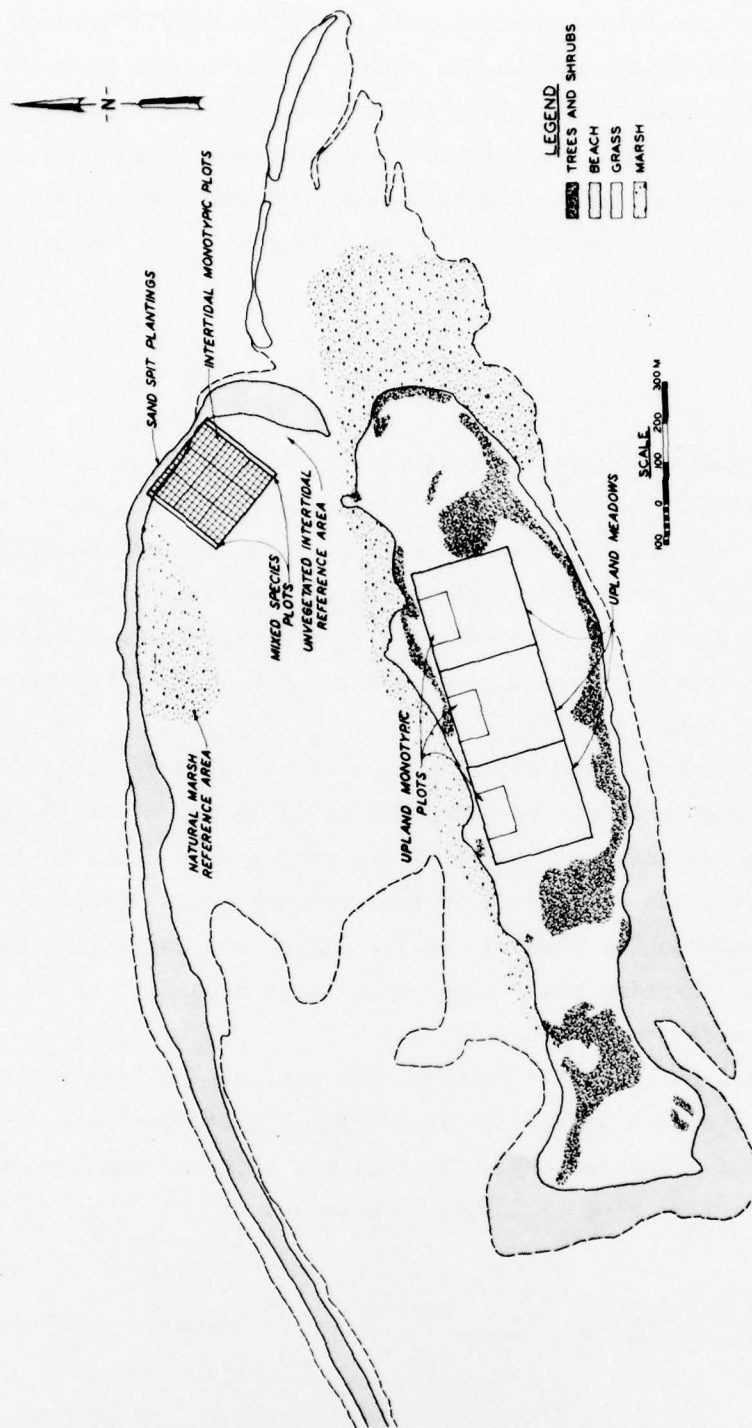


Figure 6. Field layout of the intertidal and upland study areas at Miller Sands

35. Other engineering assistance was also necessary because continuous erosion on the channel side of the sand spit created a potential hazard to the vegetative plantings within the cove. Therefore, between 27 June and 25 July 1976, 144,000 m³ of dredged material were placed on the sand spit without creating adverse effects to the vegetated areas. A similar disposal operation was accomplished between 25 October and 8 November 1977 when 81,000 m³ of dredged material were deposited on the spit.

Project Costs

36. Expenditures for the Habitat Development Project at Miller Sands were divided into two general categories: (a) construction and maintenance costs and (b) research costs. Construction and maintenance costs included expenses for dredging operations, subsurface explorations and profiles, grading of dredged material and plot layout, elevation surveys, and contracted plant propagation. All other costs were considered to be research costs.

37. Construction and maintenance costs totaled \$767,993 (Table 1). This figure includes costs for disposal of 1,074,000 m³ of dredged material and plant propagation costs. Plant propagation costs in this study were expensive because of an exact research design in which numerous plots were individually planted and fertilized and many plant species were used. By planting fewer species in large areas, plant propagation costs could be reduced substantially.

38. Research costs for funding nine separate studies and Portland District support were \$521,063. Total direct costs for developing the Miller Sands site and for assessing the environmental impacts of the dredging operations were \$1,289,056 (Table 1).

PART IV: BOTANY

Methods and Materials

Intertidal studies

39. Experimental design. The intertidal studies were conducted in planted plots, a natural reference marsh, and an unvegetated intertidal reference area (Figure 6). The planted plots were situated within an intertidal area which sloped from about MLLW to 2.1 m above MLLW. Eight species of plants were tested in the intertidal plantings: tufted hairgrass, Lyngby's sedge, slough sedge (*Carex obnupta*), broadleaf arrowhead (*Sagittaria latifolia*), American bulrush (*Scirpus validus*), common rush (*Juncus effusus*), yellow flag (*Iris pseudacorus*), and water plantain (*Alisma plantago-aquatica*). These species were selected on the basis of success in an earlier pilot study, and/or because they were believed to be of value to wildlife in the lower Columbia River estuary.

40. The intertidal plantings, as shown in Figure 5, were established in a series of planted study plots. Two basic types of plots were employed: a block of 270 monotypic (single species) plots measuring 214 m by 214 m, and two mixed species plots each 214 m by 10 m, bordering the monotypic plots. Each monotypic plot measured 11.9 m by 14.2 m and was bordered by a 1.0-m unplanted buffer. Within the monotypic plots an array of 30 experimental treatments were conducted. The monotypic experimental treatments included two plant species and an unplanted or control species, two types of propagules, five fertilizer rates, and three elevational tiers. Each treatment was replicated three times. Only tufted hairgrass and slough sedge were planted in the monotypic plots.

41. The mixed species plots were located in elongate rectangles across the elevational gradient bordering the north and south sides of the monotypic plots. Eight species, listed above, were tested in the mixed species plots.

42. Experimental procedure. All species were sprigged and seeded in July and August 1976. Because of poor results from the first seeding,

a second seeding of tufted hairgrass and slough sedge was conducted in the monotypic plots in May 1977. Sprigs in the monotypic plots were planted at 0.5-m intervals with 594 sprigs per plot (Figures 7 and 8). Seeds in the monotypic plots were broadcast by hand at a rate of 16,900 seeds per plot ($100/\text{m}^2$) during the first planting and 34,000 seeds per plot ($200/\text{m}^2$) during the second planting. The mixed species plots were sprigged and seeded with 20 alternating rows of Lyngby's sedge, slough sedge, tufted hairgrass, American bulrush, common rush, and arrowhead (seeds only). All sprigged plants were placed at 0.5-m intervals with the rows traversing the three intertidal elevational ranges (Figure 9). Because of insufficient sprigs of yellow flag and water plantain, these species were established only at the upper elevation.

43. All fertilization was conducted using 11.7-11.7-11.7 inorganic fertilizer spread at low tide with a hand-held cyclone seeder. Fertilizer was applied to the monotypic plots in one of five treatments: 0 kg/ha; * 1220 kg/ha at time of planting; 2440 kg/ha at time of planting; 610 kg/ha at time of planting and 610 kg/ha in April 1977; 1220 kg/ha at time of planting and 1220 kg/ha in April of 1977. The fertilizer applied to the monotypic plots was raked in during the first application but not raked in during the spring application (Figure 10).

44. Fertilizer was applied to the mixed species plantings at the time of planting at a rate of 2440 kg/ha. The mixed species area was again fertilized at a rate of 610 kg/ha in May 1977. Neither application was raked in and a substantial, although unknown, amount of fertilizer was washed away by the tide.

45. Seed germination tests were conducted on all species planted to determine appropriate storage conditions and seeding rates (Maguire and Heuterman 1978). Details of the propagule procurement, handling, and planting techniques are presented by Ternyik (1978). Botanical variables monitored included survival, percent cover, and root and shoot biomass. A detailed account of the sampling procedures used to

* Although 11.7-11.7-11.7 fertilizer was used, application rates of N-P-K were calculated and are provided based on 10-10-10 fertilizer.



Figure 7. A wooden rake with nails placed on 0.5-m centers was used to mark locations for planting of intertidal monotypic plots



Figure 8. Planting of transplants in intertidal monotypic plots



Figure 9. Two rows of sprigs inclosed each row of seed
in the mixed species plots



Figure 10. Raking fertilizer into a tufted hairgrass (Deschampsia caespitosa) monotypic plot

monitor plant performance under the various experimental treatments are presented by Heilman et al. (1978).

46. The natural marsh and unvegetated intertidal reference areas were monitored to provide botanical data that could be used for comparison with the intertidal plantings. All three areas had similar substrate types and elevational ranges. Cover and plant production estimates were made within the natural marsh. Plant cover estimates were made within the unvegetated reference areas to monitor natural invasion.

Upland studies

47. Experimental design. Two areas were planted above tidal influence: the sand spit near the planted intertidal plots and portions of the upland meadow (Figure 6). The sand spit plantings consisted of European beachgrass (*Ammophila arenaria*) to the east of the intertidal plantings to reduce sand erosion.

48. Plantings within the upland meadows consisted of seeding small experimental plots with individual species (monotypic plots) and seeding three large meadows with three different seed mixtures, each consisting of two grasses and one legume species (Figure 11). Each meadow measured 242 m by 248 m. A block of 36 monotypic plots (totaling 70 m by 117 m) was located within each meadow. Together the three meadows comprised 18 ha. The species used for both the monotypic plots and the large meadows included red clover (*Trifolium pratense*), white clover (*Trifolium repens*), hairy vetch (*Vicia villosa*), barley (*Hordeum vulgare*), tall wheatgrass (*Agropyron elongatum*), Oregon bentgrass (*Agrostis oregonensis*), reed canarygrass, red fescue (*Festuca rubra*), and tall fescue (*Festuca elatior*).

49. Experimental procedures. Stem cuttings of European beachgrass were planted in January and May 1977 on 0.5-m centers. Nitrogen fertilizer (21-0-0) was applied twice to the January planting at a rate of 224 kg/ha at the time of planting and 224 kg/ha three months later. The May plantings were fertilized in that month at a rate of 448 kg/ha. Two redwood lath fences were erected to further reduce erosion.

50. The site for the monotypic plots and upland meadow plantings was prepared by repeated disking and plowing. The purpose of the site

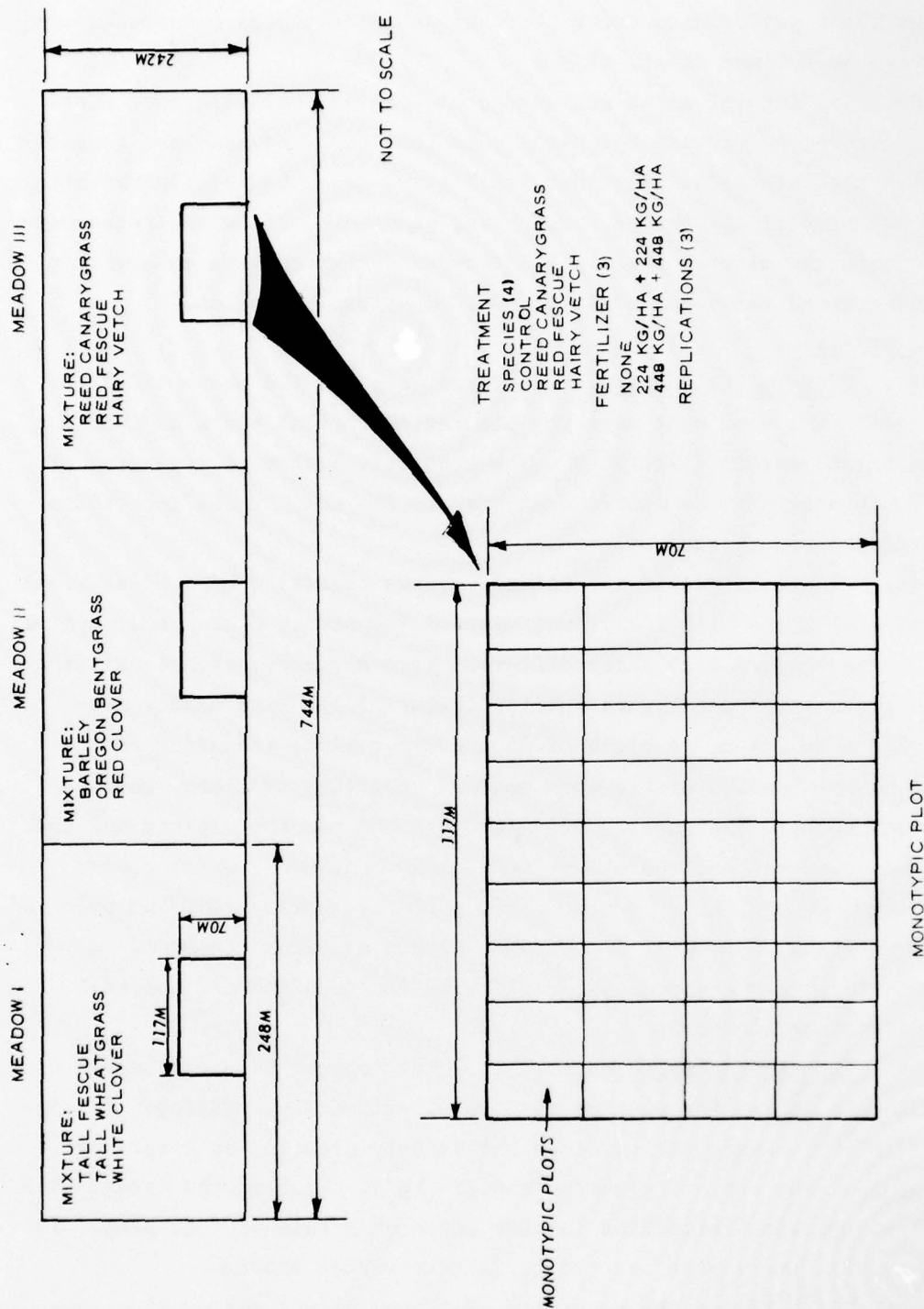


Figure 11. Layout design of the upland plantings indicating relationship of the three meadows and three groups of monotypic plots

preparations was to clear and level the area and prepare a seed bed (Figure 12). The upland meadows were fertilized (11.7-11.7-11.7) in September 1976 and May 1977. The initial rate was 224 kg/ha* and the final rate was 448 kg/ha. Each of the monotypic plots was fertilized twice (October 1976 and April 1977) at one of the following rates: 0 kg/ha; 224 kg/ha; and 448 kg/ha. The meadows were fertilized with a tractor-mounted cyclone spreader (Figure 13); the monotypic plots with a hand-held cyclone seeder.

51. Seeding the upland meadows and monotypic plots occurred in October 1976. All species were seeded at a rate of approximately 300 seeds per m^2 , with the exception of reed canarygrass and red fescue, which were accidentally seeded at a rate of about 30 seeds per m^2 . The meadows were seeded with a tractor-mounted cyclone seeder and the seeds rolled in with a cultipacker. The monotypic plots were seeded with a hand-held cyclone seeder, raked-in to a depth of 0.6 cm, and compacted with a cultipacker.

Results and Discussion

Intertidal studies

52. Monotypic plots. Tufted hairgrass and slough sedge in the monotypic study plots were successfully established from sprigs in the upper two-thirds of the tidal range (Figure 14). For unknown reasons, poor results were obtained with planted seeds. The sprigged tufted hairgrass transplants produced an abundant seed crop, resulting in the development of dense stands of seedlings on formerly bare areas adjacent to the study plots. No seeds were produced by the slough sedge plantings.

53. Tufted hairgrass transplants responded well to fertilizer applications; however, fertilizer was not apparently a factor in long-term survival of this species, and one year after planting no difference was detected between fertilized and unfertilized plants. No significant

* Although 11.7-11.7-11.7 fertilizer was used, application rates of N-P-K were calculated and are provided based on 10-10-10 fertilizer.



Figure 12. Final seedbed for upland meadows and upland monotypic plots



Figure 13. Application of fertilizer on the upland meadows using a tractor and mounted cyclone spreader



Figure 14. Intertidal monotypic plots 10 months after planting response to fertilization was detected among the slough sedge plantings. It is interesting to note that depletion of available nutrients in the substrate had occurred in the upper elevations by September 1977. It is unknown if this nutrient depletion was the result of plant uptake or rapid leaching through the sandy dredged material; however, the latter appears more likely. Tufted hairgrass transplants were more productive than slough sedge transplants and compared relatively well to native stands of tufted hairgrass growing at similar elevations. Slough sedge did not occur in the natural reference marsh. Elevation, or inundation, appeared to be the dominant factor in the success or failure of transplants. By comparison, the effects of extrinsic factors such as sand accumulation, animal damage, variation in both the chemical and physical conditions of the planted substrate, and erosion and tidal channel development were minimal.

54. Mixed plantings. Results from the mixed plantings suggested that those planted species may also be useful for marsh establishment in

similar habitats, as good survival was obtained for all transplanted species. No positive results were obtained when seeds were used for any of the species planted.

55. Unvegetated reference area. Natural establishment of vegetation on the originally unvegetated reference area was generally limited. Vegetation that became established was most commonly in the upper two-thirds of the intertidal range and was essentially restricted to areas protected from current and wave action. The plant species invading this area originated from seeds or rafted plants and occurred in the nearby reference marsh.

Upland studies

56. Sand spit plantings. The European beachgrass sand spit plantings of January and May 1977 were both successful, and both exhibited comparable aboveground plant production by October 1977. No significant response to fertilization was noted.

57. Upland meadow plantings. Following seeding in mid-July 1976, red clover, white clover, hairy vetch, tall fescue, Oregon bentgrass, barley, and tall wheatgrass became well established in the fertilized meadows and monotypic plots (Figure 15). Application of 448 kg/ha of fertilizer greatly enhanced the establishment of these plants. These areas also yielded aboveground biomass values that were significantly higher when compared to unfertilized plantings or plantings fertilized at a lower rate of 224 kg/ha. Additionally, the 448 kg/ha fertilizer rate generally produced more vigorous and competitive legumes as compared with those results obtained from the use of the 224 kg/ha rate. Fertilizer application also generated considerable competition from two grass invaders, common velvetgrass and rat-tail fescue (*Festuca myuros*), but reduced competition from common broadleaf invaders and from moss species.

58. Red fescue and reed canarygrass did not establish well under any of the experimental treatments. Reasons for this poor development are unknown; however, the low seeding rate used was probably the cause.

59. Hairy vetch plantings were successful during 1976 and during the beginning of the 1977 growing season; however, during the early spring of 1977 hairy vetch seedlings became infected with spring black



Figure 15. The upland meadow treatments produced a dense stand of vegetation

stem rust disease (*Ascochyta imperfecta*), causing a significant decline in ground cover and biomass by the latter part of the 1977 growing season.

60. In addition to the natural invasion by common velvetgrass and rat-tail fescue, re-invasion of the planted grassland area by common scouring-rush was also evident by the fall of 1977 in those areas where plant density was low. In areas with dense stands of planted legumes and grasses, re-invasion by common scouring-rush was reduced. Without repeated fertilization it is unlikely that the density of the grass-legume mixture will be maintained and therefore re-establishment of common scouring-rush can be expected.

61. The plant composition of the untreated area adjacent to the meadows remained essentially the same throughout the period of study with common scouring-rush comprising a major portion of the total biomass.

produced in this area. Common velvet grass, stream lupine (*Lupine rivularis*), rat-tail fescue, and mosses also were prominent in this area.

Conclusions and Recommendations

Intertidal studies

62. The success of the intertidal plantings demonstrated the potential feasibility of propagating selected marsh plants on unconfined coarse-grained dredged material. Marsh can be established at this or similar sites for a total cost of about \$1,100/ha (Ternyik 1978).

63. Successful establishment of tufted hairgrass and slough sedge was accomplished through the use of transplant sprigs, whereas direct seeding was not successful. Therefore, seeding is not recommended for the establishment of these two species. This is not to say that marsh propagation by seeding does not have potential, but that the state of the art has not sufficiently advanced to the stage where one can rely on seeding as a means of establishing tufted hairgrass and slough sedge on habitats similar to Miller Sands.

64. The magnitude, duration, and frequency of tidal inundation have a significant influence on the successful establishment of tufted hairgrass and slough sedge. Planting of these species is not recommended along portions of the intertidal range where inundation occurs more than 60 percent of the time.

65. Fertilizer application had no significant effect on the successful establishment or the production rates of tufted hairgrass and slough sedge. Rapid leaching of fertilizer from the upper portions of the coarse-grained sandy dredged material substrate is strongly suspect as the reason for this result. Although a quick-release fertilizer of the type used in this study is not recommended for the establishment of slough sedge and tufted hairgrass on sandy substrates, a slow-release fertilizer may have the potential to enhance marsh establishment and increase plant production.

66. Results of the intertidal mixed planting study using sprigs as propagules for Lyngby's sedge, American bullrush, and common rush, and

rhizomes for yellow flag and water plantain demonstrated the potential use of these species in similar habitats. However, these species are not recommended for large-scale habitat development projects until more detailed studies are conducted. As in the monotypic intertidal studies, tidal inundation had a significant influence on the establishment of these species. It is recommended that these species not be planted along portions of the intertidal range where inundation of the substrate occurs more than 60 percent of the time.

67. Natural establishment of vegetation on originally unvegetated areas adjacent to the intertidal planting site was generally insignificant and for the most part restricted to areas protected from current and wave action. Reliance solely on plant invasion for marsh plant development on habitats similar to Miller Sands is not recommended where rapid cover is desired.

Upland studies

68. The feasibility of planting selected species on upland dredged material deposits was demonstrated by the success of both the sand spit plantings and the meadow plantings. Experience in similar environments indicates that the European beachgrass on the sand spit is probably relatively permanent; however, the success of the meadows cannot be continued without periodic maintenance.

69. Sand spit plantings. European beachgrass is recommended to stabilize areas in the Pacific Northwest such as the sand spit at Miller Sands. This species can be rapidly and successfully established and, when properly placed, will significantly reduce erosion.

70. Upland meadow plantings. The feasibility of establishing selected plant species on an upland dredged material disposal site such as Miller Sands has been demonstrated. Upland meadows such as that established at Miller Sands could be duplicated at a similar site for a total cost of about \$600/ha (Ternyik 1978). The plantings were generally successful and produced substantially more above-ground biomass during the 1977 growing season than did the unplanted areas. However, because the soils retain little moisture and are infertile, the goal of maintaining a highly productive area probably cannot be achieved without

continued maintenance, including periodic disking, seeding, and fertilization. This may not be cost effective on a site as remote as Miller Sands. Alternative strategies might include such management techniques as the introduction of plant species more characteristic of early successional stages or incorporation of fine-textured dredged material into the sandy material to improve its fertility and water-holding capacity.

PART V: SOILS

Methods and Materials

71. Soil samples to monitor changes occurring in the intertidal and upland study plots were collected in September 1976, June 1977, and August 1977. Details of sampling methodology, sample handling, and data analysis are presented by Heilman et al. (1978).

Results and Discussion

Intertidal areas

72. Soil samples collected from the intertidal areas were classified as sand according to the USDA classification system, although soil samples at the lower elevations contained slightly more silt and clay than those at the middle and upper elevation areas.

73. Soil pH in the intertidal areas was about 7.0 throughout the study. There was a trend toward increasing soil pH with time in unfertilized areas. In fertilized areas, the pH was depressed. This pH depression resulted because (a) most fertilizer end-products are acidic and (b) fertilizer salts temporarily depress leached soils. (The low electrical conductivity of the soils, ranging from 0.5 mmhos/cm² at the low elevation to 0.22 mmhos/cm² at the High elevation indicated that the soils were leached.)

74. Exchangeable potassium levels decreased with increasing elevation for all sampling dates; only minor variations were noted among sampling dates (Figure 16a). Fertilization also influenced exchangeable potassium levels (Figure 16b). The general trend was for lowest potassium levels to be associated with the unfertilized treatments and to increase with increasing fertilizer rate.

75. Available phosphorus levels also decreased with increasing elevation (Figure 16c). Phosphorus levels tended to decline with time of sampling from September 1976, through June 1977, then stabilized or

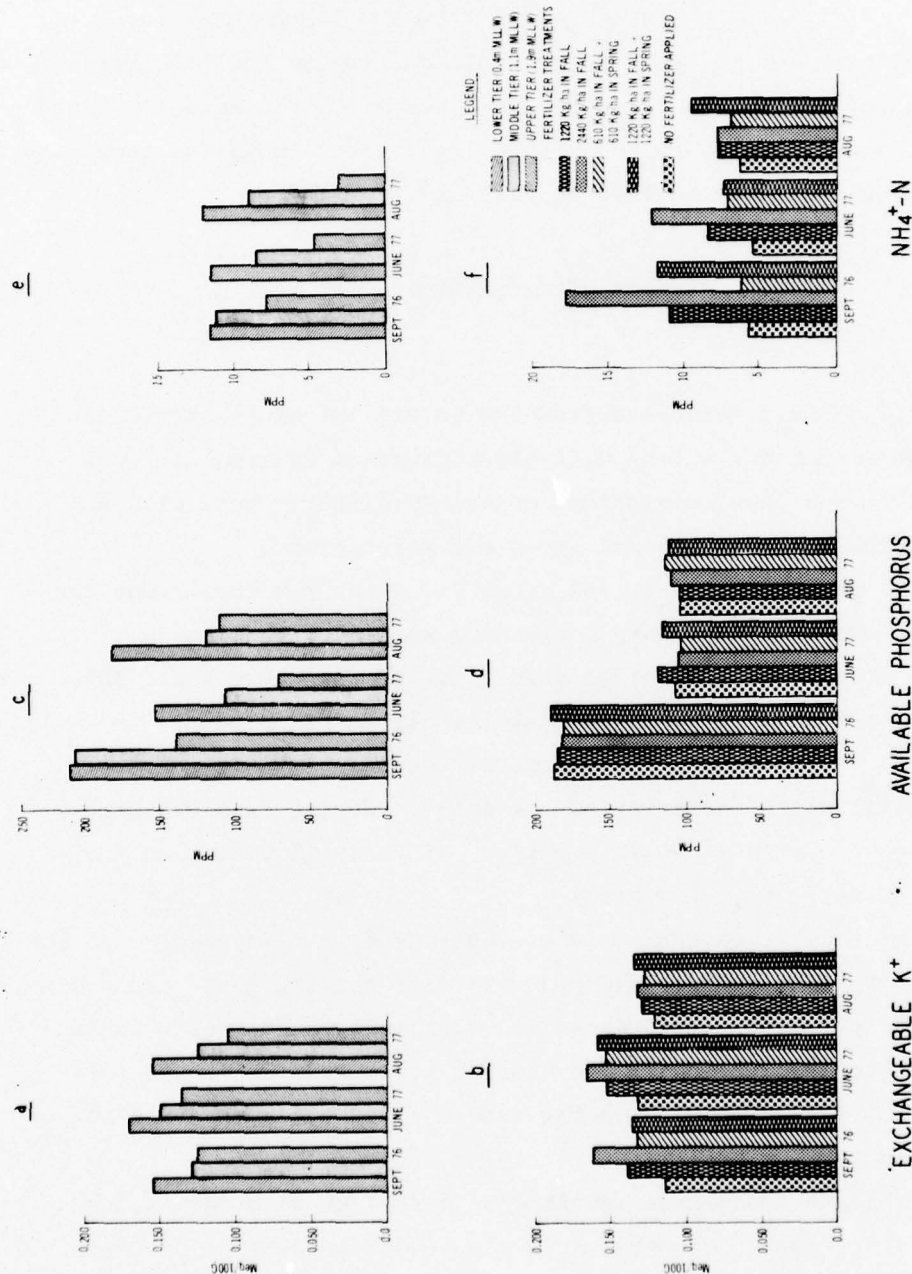


Figure 16. Marsh soil sample analyses of exchangeable potassium as influenced by sampling time and elevation (a) and by sampling time and fertilizer rates (b); available phosphorus by sampling time and elevation (c) and by sampling time and fertilizer rates (d); and ammonium nitrogen by sampling time and elevation (e) and by sampling time and fertilizer rates (f)

increased slightly between June and August 1977. The rate of fertilizer application had little influence on available phosphorus (Figure 16d). This is somewhat surprising in view of the relatively high rate of phosphorus applied in the fertilizers. This possibly indicates that the soils are capable of adsorbing relatively large amounts of phosphorus without revealing changes in available phosphorus by the extraction method used.

76. Ammonium nitrogen was also influenced by elevation and time of sampling (Figure 16e). Ammonium decreased as elevation increased. This would be expected as soil moisture would be decreased at the high elevation, thus making conditions more favorable for bacterial conversion of ammonium to nitrate. Addition of the fertilizer increased soil ammonium levels (Figure 16f) at the September 1976 and June 1977 sampling, but not the August 1977 sampling. Again, this would be expected as ammonium in the soil is either utilized by plants, converted to organic form, or nitrified over an interval of time.

77. Total Kjeldahl nitrogen decreased as elevation increased (Figure 17a); however, little change occurred with time of sampling. Fertilization had little effect on total Kjeldahl nitrogen over the sampling interval of this study.

78. Nitrate nitrogen increased with increasing elevation (Figure 17b) and with time of sampling. The elevational effect was as expected as explained above because of the conversion of ammonium to nitrate. The change with time may have been caused by the drought conditions existing in Oregon in 1977; however, soil moisture levels (Figure 17c), while tending to verify the drying effect of elevations, did not show a decrease in moisture with time of sampling. Fertilization influenced soil nitrate levels only for the August 1977 sampling date when the plots fertilized at the 1220 kg/ha rate showed nitrate levels above those observed in the plots without fertilizer.

79. Organic carbon was determined only at the initiation of the study and in August 1977. For the August 1977 samples, the values ranged from 0.32 percent at the low elevation to 0.44 percent at the high elevation. This was an increase over the initial samples for the low

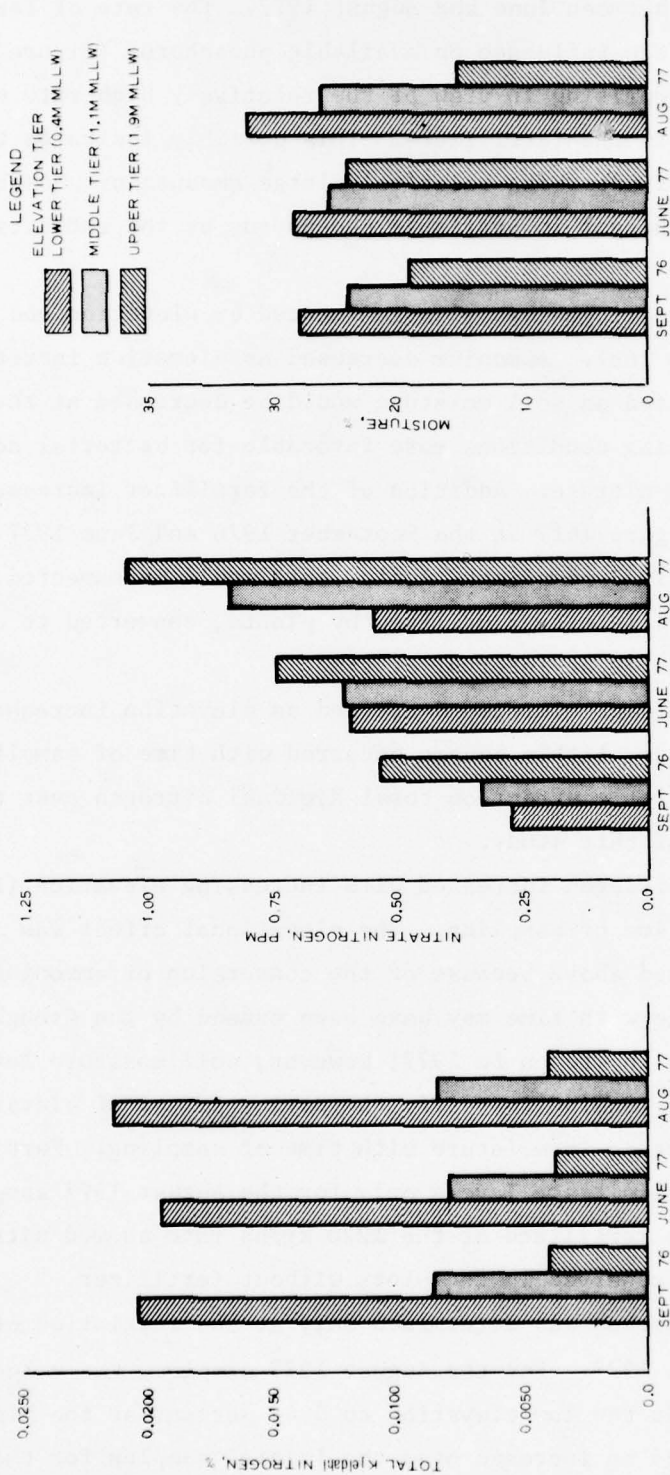


Figure 17. Marsh soil sample analyses of total Kjeldahl nitrogen (a), nitrate nitrogen (b), and soil moisture levels (c) as influenced by sampling time and elevation

elevation, but no change occurred with time at the middle and high elevations. No consistent pattern of percent carbon, as related to fertilizer treatment, could be determined for the August 1977 samples.

80. Cation exchange capacity varied from 5.87 meq/100 gm for the high elevation to 3.71 and 3.38 meq/100 gm for the middle and low elevations, respectively, for the August 1977 samples. These values indicated only minor variation from cation exchange capacity measurements in the initial marshland samples. As would be expected, cation exchange capacity was not influenced by fertilization.

Upland areas

81. Soil pH was approximately 6.0 (Table 2) for all three upland meadows. Only during one period, August 1977, were there significant differences among meadows, when the soil pH for Meadow II (Figure 11) was significantly higher than for the other two meadows. Fertilization influenced pH at both the June and August 1977 sampling dates. In June, pH was depressed by the application of 448 kg/ha of fertilizer, while in August pH was depressed for both 224 kg/ha and 448 kg/ha application rates. This pH depression was caused by the acidification of the fertilizer during conversion of ammonium to nitrates.

82. Exchangeable potassium was highest in Meadow III (Figure 11) for the initial samples, but was highest in Meadow I in both June and August 1977 (Table 2). Meadow II tended to have lower exchangeable potassium soil levels during all three sampling dates. Fertilization increased exchangeable potassium significantly only at the 448 kg/ha rate for the June samples.

83. Available phosphorus tended to be highest in Meadow III in the initial samples and highest in Meadow I for the August 1977 samples (Table 2). There was no appreciable change in available phosphorus over the time span of the study. Fertilization at the 448 kg/ha rate significantly increased available phosphorus in June whereas available phosphorus was significantly increased by both the 224 kg/ha and 448 kg/ha rates in August 1977 (Table 3).

84. Ammonium nitrogen averaged approximately 3.0 ppm initially; however, values for June and August were only approximately 0.8 and

1.5 ppm, respectively. Meadow III tended to have higher ammonium nitrogen values for both June and August (Table 2). Fertilization did not have a significant effect on soil ammonium in August (Table 3).

85. Total Kjeldahl nitrogen tended to be lower in Meadow II throughout the study (Table 2). No appreciable changes with time were noted for any of the meadows. Fertilization at the 448 kg/ha rate increased total Kjeldahl nitrogen in the soil in June, while total Kjeldahl nitrogen was increased at both the 224 kg/ha and 448 kg/ha rates in August (Table 3).

86. Soil nitrate nitrogen was highest in Meadows II and III in June and in Meadow III during August (Table 2). Fertilization increased nitrate nitrogen in June but not in August (Table 3).

87. Soil moisture was initially about 6.5 percent, but increased to 8 percent in June and 17 percent in August (Table 2). Meadow II soils contained significantly more moisture in August than in other meadows. Fertilization had no effect on soil moisture for the June samples, whereas in August there was a trend for increasing fertilizer rates to be associated with reductions in soil moisture (Table 3).

88. Soil carbon was only measured at the beginning and end of the study in September 1976 and in August 1977, respectively. Carbon levels appeared to decrease between these sampling intervals (Table 2). Meadow III had significantly less carbon in August than other meadows.

89. Cation exchange capacity was low and indicated little variation between samples collected in September 1976 and August 1977 (Table 2). Fertilization had no apparent effect on the cation exchange capacity.

Summary and Conclusions

Intertidal areas

90. Elevation had more effect on the parameters being monitored than did sampling time or fertilization. Exchangeable potassium, phosphorus, ammonium nitrogen, total Kjeldahl nitrogen, organic carbon, and cation exchange capacity were highest at the low elevation and decreased as elevation increased. Only nitrates increased with increasing elevation.

91. The results from the nitrate samples suggest that nitrate levels increased with time. Available phosphorus decreased initially with time, then tended to increase slightly.

92. Exchangeable potassium, ammonium nitrogen, and phosphorus tended to increase temporarily with increased levels of added fertilizers. This temporary effect was most prominent with ammonium nitrogen. This would be expected since ammonium nitrogen is converted to other forms of nitrogen with time or else is utilized by plants.

Upland areas

93. The upland meadows were located on sandy soils with a low cation exchange capacity and an average pH of near 6.0. There were significant differences among meadows for exchangeable potassium, available phosphorus, nitrate nitrogen, total Kjeldahl nitrogen, carbon, and cation exchange capacity, at one or more of the sampling dates.

94. Fertilization tended to depress soil pH while increasing potassium, phosphorus, ammonium nitrogen, total Kjeldahl nitrogen, and percent carbon. However, these differences were not always significant. Fertilization had no apparent effect on the cation exchange capacity of the soils. For those parameters varying with fertilization, this effect appeared to be diminishing by August.

PART VI: AQUATIC BIOLOGY

Materials and Methods

95. Aquatic biology studies were designed to document changes in abundance, biomass, and composition characteristics of the aquatic animal communities inhabiting the intertidal and subtidal areas of the Miller Sands site. Field collections were conducted during three periods to relate biological observations to site development conditions. A baseline survey was conducted in March, May, and July 1975 to examine existing aquatic resources prior to the planned dredged material disposal operations in July 1975. After disposal operations were completed, aquatic biota were sampled in August, September, and November 1975 and January and March 1976. In July 1976 a plant propagation program was begun in the intertidal area of the cove and on the older island. The sampling program was modified slightly from previous collections and samples were obtained in July, September, and November 1976 and in March, May, and July 1977.

Fish

96. During the period prior to July 1976, fish were collected with a beach seine that was 76.2 m long and 3.7 m deep with a 12.7-mm stretched mesh. Fish samples were collected from four stations within the cove and one station upstream from Miller Sands outside the cove (Figure 18). In July 1976, the sampling scheme was modified to provide more detailed information about the community characteristics of selected developed and natural habitats at the site. Two more beach seine stations were added to the cove sampling scheme and the outside station was omitted. Six fyke net stations were also added to sample an unvegetated intertidal reference area, a natural reference marsh area, an area of intertidal mixed species plots (two stations), an intertidal area of planted monotypic plots, and a subtidal area in the center of the cove (Figure 6). The fyke nets had a D-shaped opening approximately 1 m in diameter. Mesh at the first hoop was 12.7 mm stretched measure; 0.63-mm mesh was used for the remainder of the net. The attached wings were

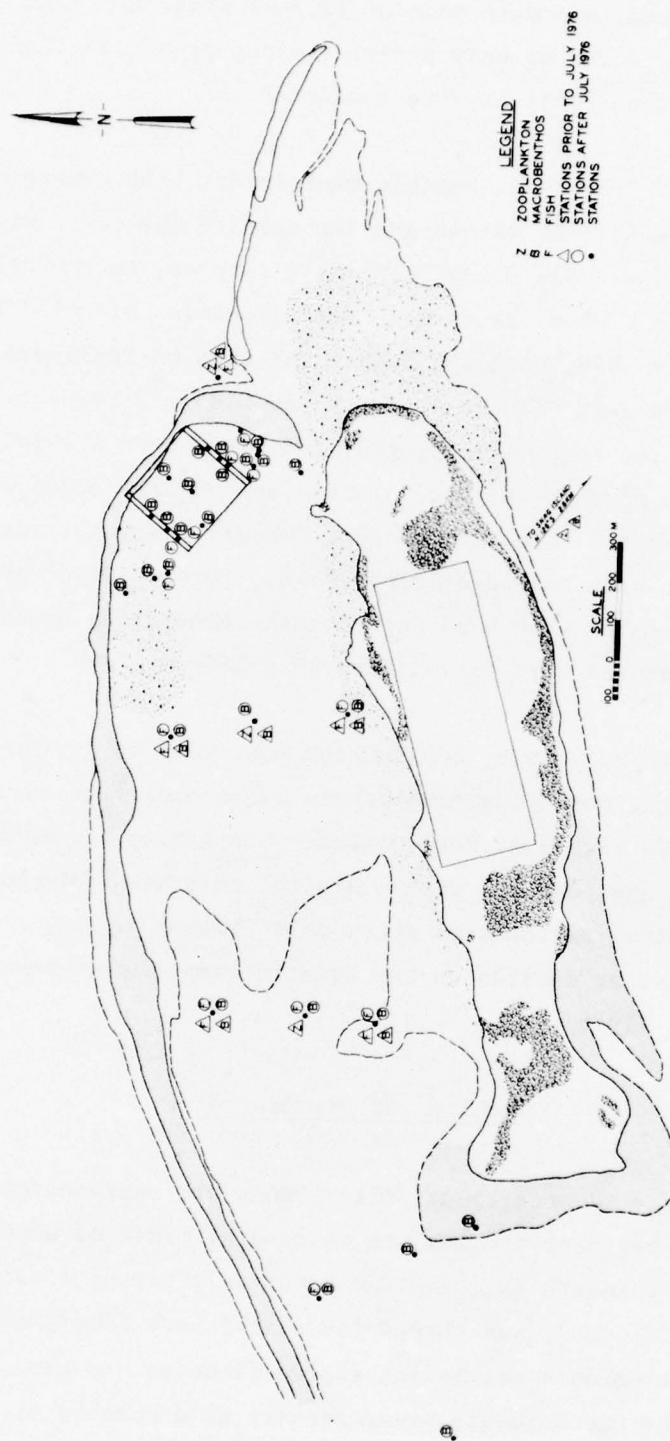


Figure 18. Aquatic sampling stations prior to and after July 1976

3 m long, 0.9 m deep, and were made of 12.7-mm stretched mesh. Prior to July 1976 sampling occurred only during the daylight hours; after that date day and night collections were conducted.

Benthos

97. Prior to July 1976, benthic macroinvertebrates were collected from seven locations, five within and two outside the cove, with a 0.05-m^2 Ekman dredge. Six 0.1-m^2 replicate samples, each consisting of a composite of two 0.05-m^2 Ekman grab samples, were collected from each location. In July 1976, both the number and size of replicate samples from each location were reduced to three and 0.05 m^2 , respectively; two stations outside the cove were dropped; and other cove stations were added. Transects through selected planted and natural areas were also added in July 1976 to characterize conditions in the intertidal habitats sampled with fyke nets and identified above. Three 0.05-m^2 by 10-cm-deep replicate samples were hand dug at three elevations along each transect. All samples were sieved through a $580\text{-}\mu\text{m}$ sieve.

Zooplankton

98. Prior to July 1976, zooplankton were sampled during daylight hours at four locations using five-minute horizontal surface tows. Collections were made with a 12.7-cm-diameter Clark-Bumpus sampler having a No. 6 mesh bag and equipped with a digital recording flow meter. Zooplankton sampling was omitted after July 1976.

99. For further details on the aquatic sampling program, see McConnell et al. (1978).

Results and Discussion

100. The fish community at Miller Sands was represented by a total of 21 species. Dominant species, in descending order of abundance, were chinook salmon, peamouth (*Mylocheilus caurinus*), starry flounder (*Platichthys stellatus*), and threespine stickleback (*Gasterosteus aculeatus*). The chinook salmon and starry flounder are transient species which use the Columbia River estuary as a nursery area during the first and/or second year of development. Young chinook salmon were

most abundant in March and May following the downstream migration from spawning beds. This migration pattern was most apparent at the station outside the cove in May 1976 where 2,152 chinook salmon were taken in a single seine haul. The starry flounder was most abundant at the site in July following its upstream migration after spawning in February and April at the mouth of the river.

101. Peamouth and threespine stickleback are considered resident species in the freshwater Columbia River, even though stickleback are typically more marine as one proceeds farther north (Carlander 1969); both species spawn in May and June. Peamouth typically spawn over gravel (Carlander 1969) and threespine stickleback construct elaborate nests (Clemens and Wilby 1961; Hart 1973) of grasses (Eddy 1969). Neither spawning habitat was available at the field site since it was composed primarily of sand and most of the vegetated areas were exposed during low tides. Therefore, these two species probably were attracted to the field site for reasons other than for spawning. No apparent seasonal periodicity was evidenced for either species during the study; sporadic peaks in abundance during the summer were caused primarily by large catches at one or two seining stations.

102. The site construction and plant propagation activities seemingly did not influence abundance of the fish community as indicated by fish catch during site development activities. A comparison between the abundance of fish caught during similar seasons and at similar stations during each of the three phases of site development indicated that 25 percent were obtained prior to site construction activities, 42 percent were obtained after site development but before propagation, and 33 percent were obtained after plant propagation. Within the cove there was a sharp reduction in the abundance of fish captured in August 1975 (Figure 19). The reduction continued until May 1976 and may have been the result of dredging and disposal operations in July 1975. However, other factors could also be responsible for this apparent decline in fish use of the area because the catch outside the cove exhibited a similar decline. This decline suggested that the reduction in the number of fish caught could have been the

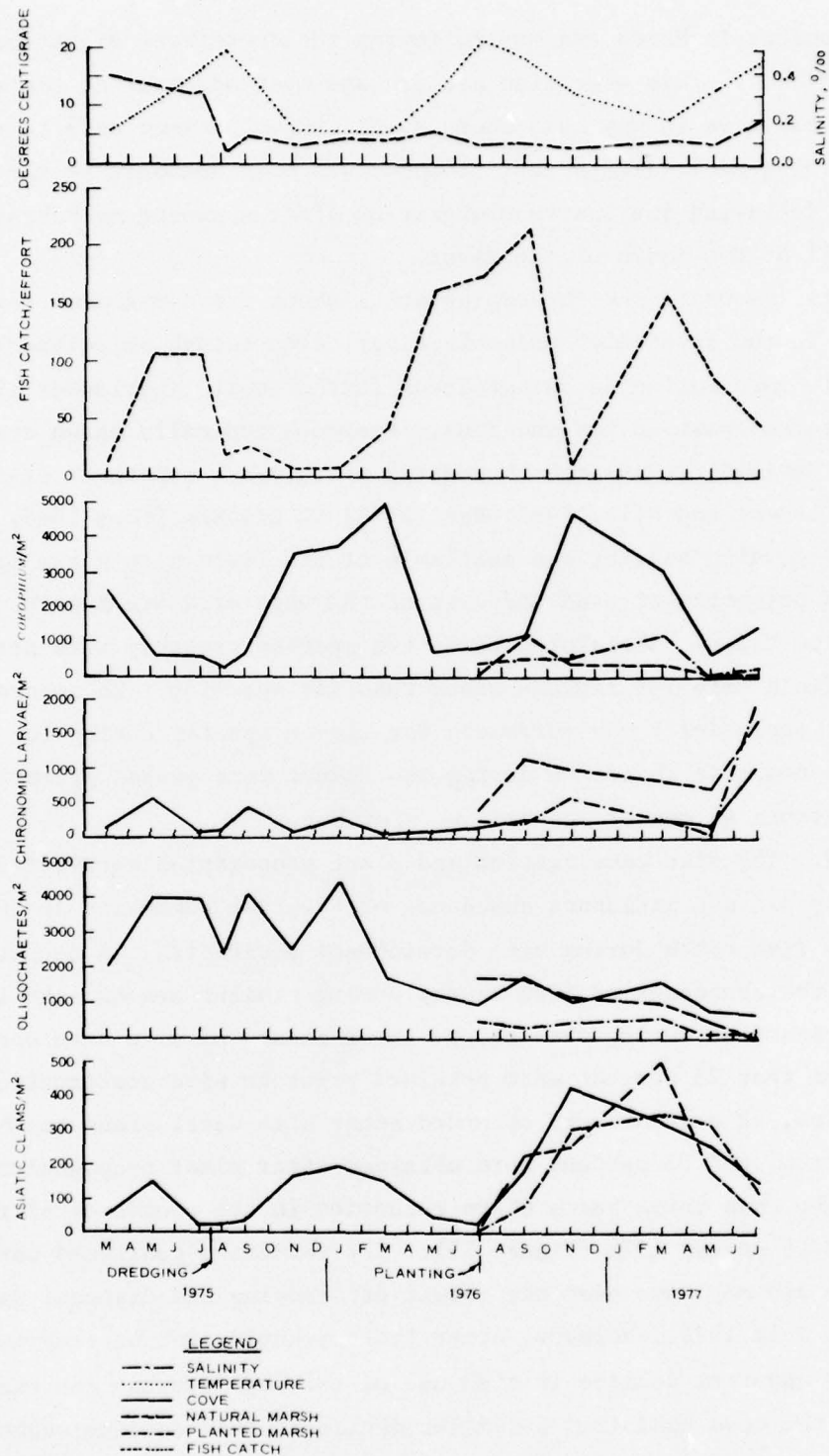


Figure 19. Seasonal distribution of aquatic biota and selected water quality parameters at Miller Sands

result of a normal seasonal decline in the fall fishery. A decline in the catch was also noted in July during the following year, when, as in the previous year, catch was lowest in November. Catch for all species except chinook salmon remained low from November 1976 until March 1977.

Fish abundance in the cove

103. Based on an examination of beach seine data and considering the number and species of fish caught per unit effort, the areal distribution of fish within the cove was fairly uniform during each sampling period. Slightly more fish were collected along the old island than along the sand spit but the difference was not statistically significant. Considerably more fish were collected at the beach seine station nearest the intertidal plantings, but this was a result of a single night seine haul in July 1976 when 1,442 peamouth were captured. Plant establishment in the intertidal area had not been completed when this seine haul was made and subsequent collections in the area were less than one-tenth of this large haul.

Fish abundance in the developed intertidal habitats

104. Distribution of fish in the planted intertidal area was determined from the fyke net catch. No appreciable difference in the catch between any of the five intertidal fyke net stations was detected. The lowest total catch was obtained from the area of mixed species plots south of the intertidal monotypic plots whereas the largest catch was obtained from the area of mixed species plots north of the intertidal monotypic plots (Figure 6). No apparent reason was determined for the extremes in catch at these two similar habitats.

Results of day and night collections

105. Nearly equal numbers of fish were obtained during both day and night collections, indicating that time of day had little impact on fish presence.

Benthic community studies

106. The benthic communities in the area of the habitat development site were overwhelmingly dominated by the amphipod *Corophium salmonis*, oligochaetes, chironomid larvae, and the Asiatic clam, all

of which are well adapted to a wide range of environmental conditions. The physical environment at the site is rigorous and characterized by a 1.9-m mean tidal range, wind-generated waves, and occasional intrusions of salt water (Cutshall and Johnson 1977). The intertidal and subtidal sediments at Miller Sands were very uniform well-sorted fine sand to muddy fine sand and did not change appreciably during the course of the studies. Both the percentage of fines and organic matter tended to increase with time, but not consistently. No gross changes in the sedimentary regime because of habitat development activities were detected.

107. The combination of a physically controlled environment and a tolerant benthic community made detection and interpretation of habitat development effects difficult. Except for the animals buried by the dredged material, there were no acute effects detected from the dredging and site construction activities. Planting activities at the marsh habitat also had little apparent effect on the benthic community. The marsh was planted at a time of lowest benthic standing stock just before seasonal increases in the fall (Figure 19). Consequently, there were no obvious adverse impacts from the marsh development. The undetectable acute impacts demonstrate the resilience of the benthic community in the tidal freshwater Columbia River. This general tolerance and resilience seems to be common to tidal freshwater benthos. Acute impacts were also found to be insignificant at another tidal freshwater habitat development site in the James River, Virginia (Lunz et al. 1978).

Seasonal changes in
the benthic community

108. Maximum densities of benthos occurred in the fall and winter. Of the four dominant organisms, *Corophium salmonis*, chironomid larvae, and the Asiatic clam all exhibited typical seasonal fluctuations, having high density in fall and winter in both the cove and intertidal marsh areas. These typical fluctuations suggested that the habitat development activities at Miller Sands did not appreciably affect the benthos. Oligochaetes, the fourth dominant organism, declined steadily from January 1976 to July 1977 in both the cove and marsh habitats. This decline was most likely a result of some other environmental variable,

such as the changes in river flow, and not directly associated with the habitat development activities. Salinity started to increase in July 1977 but did not rise enough to account for the drastic decline of oligochaetes (McConnell et al. 1978).

109. When the planted marsh was compared with an adjacent natural marsh there were no consistent differences between the two areas in abundance and diversity of benthos. The natural reference marsh had slightly higher numbers of chironomid larvae and oligochaetes but their distribution was very patchy and there were no significant ($P \leq 0.05$) differences between the two marshes.

Habitat value

110. Fish stomachs were examined after plant propagation in order to assess the potential of the field site to support organisms consumed by fish. Nine species of fish were examined including the four most abundant species.

111. Overall, the principal food items consumed were two zooplankton species (*Daphnia longispina* and *Eurytemora hirundoides*), an amphipod (*Corophium salmonis*), and chironomid pupae and larvae. These five organisms composed 96 percent of the total number of items consumed. Zooplankton samples collected from March 1975 to May 1976 indicated that zooplankton abundance was greater inside the cove at the field site than at an open river area or at a nearby natural marsh area. *Daphnia*, the most abundant food item consumed, comprised 80 percent of the zooplankton collected; *Eurytemora* ranked fourth in abundance. Benthic samples collected during the study indicated that *Corophium salmonis* and chironomid larvae comprised 50 percent of the benthic organisms collected and ranked second and third, respectively, in abundance. Chironomid pupae, usually located within the water column, were not abundant in either zooplankton or benthos samples.

112. Seasonal abundance of major food items also coincided with seasonal consumption except that chironomid larvae were consumed uniformly throughout the study. Zooplankton samples indicated that *Daphnia* and *Eurytemora* were most abundant in August and September and declined sharply in November. This seasonal peak period of abundance coincided

closely with consumption by fish as chinook salmon, starry flounder, and threespine stickleback fed heavily on *Daphnia* in July and September and on *Eurytemora* in November. A similar seasonal relationship was observed between benthic abundance and consumption by fish. *Corophium salmonis* were abundant in the benthic samples from the fall to early spring (Figure 19), a period when fish activity was low. However, abundance of downstream migrating chinook salmon peaked in March when *Corophium* were also most abundant. A sharp decline in abundance of this amphipod was observed in July, likely because of predation by chinook salmon but also because of predation by starry flounder and threespine stickleback which also fed heavily on *Corophium* from March through July.

Summary and Conclusions

113. Twenty-one fish species were collected at Miller Sands during the course of the study but 91 percent of the specimens collected were dominated by only four species: chinook salmon, starry flounder, peamouth, and threespine stickleback. Variations in abundance of most dominant species followed expected seasonal trends with the highest numbers in the spring and lowest numbers in the winter. Areal distribution within the cove and intertidal marsh areas of the habitat development site at Miller Sands was fairly uniform.

114. The benthic community exhibited normal seasonal trends in abundance and uniform distribution within the habitat site. The only exception to this trend was oligochaetes which declined steadily after January 1976 for unknown reasons.

115. Dominant benthic organisms collected were *Corophium salmonis*, chironomid larvae, oligochaetes, and the Asiatic clam. Two of these organisms, *Corophium salmonis* and chironomid larvae, were among the principal food items consumed by the fish. Other important food organisms consumed by fish were *Daphnia longispina*, *Eurytemora hirundoides*, and chironomid pupae. Plankton samples taken prior to July 1976 indicated that *Daphnia* and *Eurytemora* were more abundant at the site than at an open river area or a nearby natural marsh. Zooplankton were abundant

at the site in August and September 1975, but no samples were taken concomitantly with the food habits study. The food habits study indicated that several important planktonic and benthic food organisms consumed by fish were available at the site and were heavily consumed during periods of seasonal abundance.

116. Site development activities seemed to cause little change in the fish or benthic community. The lack of detected acute impacts from site development activities is likely a result of the ability of fish to move into and out of the habitat site and the resilience of the tidal freshwater benthic community to perturbations. The aquatic environment at Miller Sands is physically controlled with tidal and wave influences being important. The small size of the planted marsh and the early stage of development are also likely contributing factors to the undetected influence of site development activities at Miller Sands.

PART VII: WILDLIFE

Methods and Materials

117. Animal populations on Miller Sands were inventoried in April, May, and June of 1975 prior to plant propagation (Woodward-Clyde Consultants 1978). Birds were surveyed by the sample-count method of Bond (1957) on 900-m transects established in each of five general habitat types: cottonwood-alder, grassland, willow-alder, freshwater marsh-mud flat, and sand spit. Small mammal trapping grids were set in tree and grassland habitats, and the bird transect lines were walked to detect larger mammals and their sign. A detailed description of methods is found in Woodward-Clyde Consultants (1978).

118. After plant propagation, from July 1976 through August 1977, bird, mammal, and terrestrial invertebrate populations were sampled to document wildlife use of the site. Fifteen areas in, adjacent to, and away from the plantings (Figure 20) were chosen to sample and compare bird species composition, density, and diversity. Birds were sampled twice monthly with a variable plot technique on transects in each of the habitat types between sunrise and 2.5 hr after sunrise. Densities were estimated from data taken at three observation stations on each transect. The Shannon and Weaver (1949) index was used to calculate diversity. Relative intensity of grazing by Canada geese (*Branta canadensis*) and snow geese (*Chen caerulescens*) in upland plantings was estimated by determining the density of their droppings. Bird nest searches were conducted in July and August 1976 and April through July 1977.

119. Small mammal live-trapping grids were set every three months in the meadows for seven nights each time and less regularly in the intertidal area. Mouse-trap, rat-trap, and live-trap lines were set subjectively in tree-shrub habitats for inventory purposes. A high population of nutria occupied the island prior to habitat development activities, posing a potential threat to experimental plantings of vegetation. A nutria control program was begun in June 1976 and continued through November 1977. Nutria were dead-trapped on Miller Sands

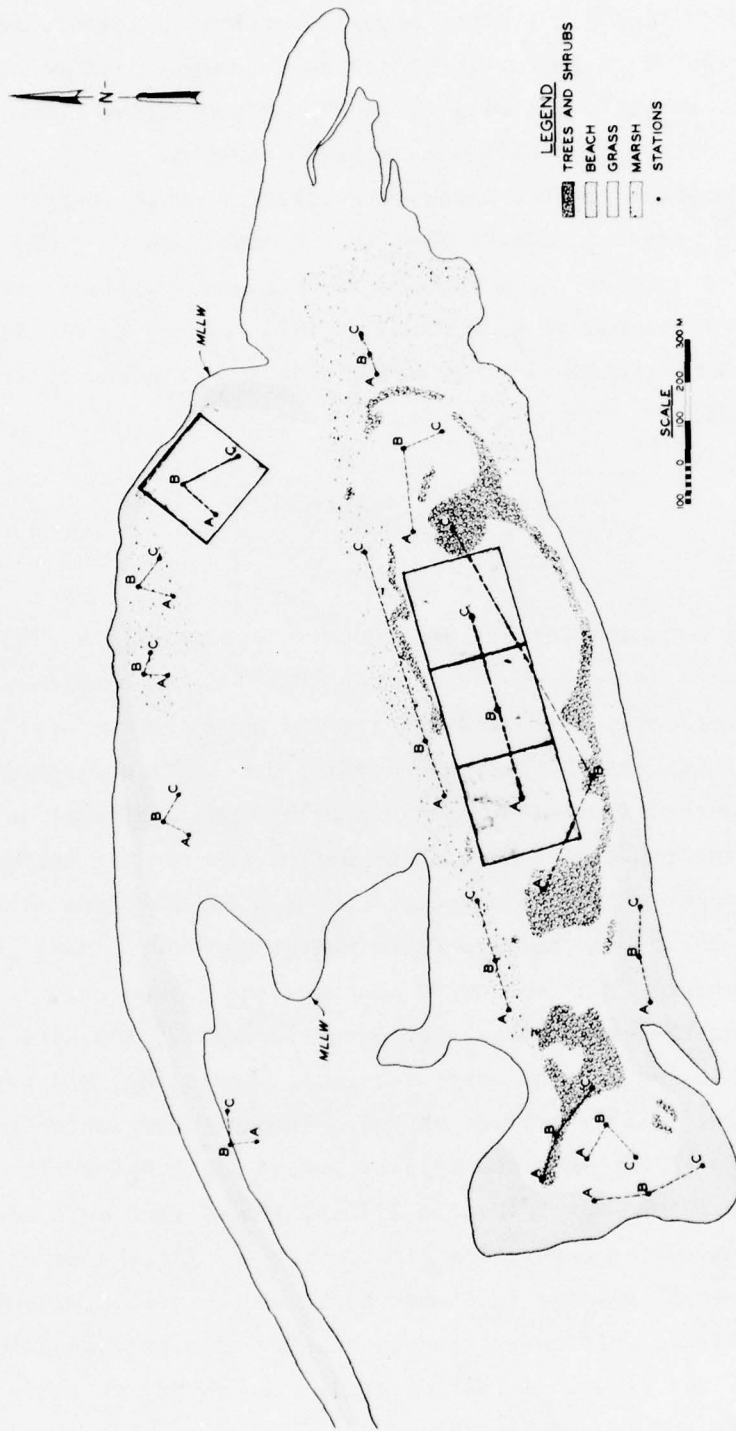


Figure 20. Location of bird observation stations. A, B, and C indicate observation stations. Dashed lines were not transects joining stations, but illustrate station groupings for the convenience of the reader

to prevent them from grazing the plantings. On other islands within a 6.4-km radius of Miller Sands, they were live-trapped, tagged, and released at the point of capture. Recapture data were also recorded, and included determination of weight, length, reproductive state, and location taken. These data will be analyzed later.

120. Terrestrial invertebrates were collected with sweep-nets along six 300-m by 1-m transects established in the experimental areas and in areas adjacent to and away from them for comparison. Collections were made every two months except from December 1976 through April 1977.

121. Further details on study methodologies are given in Crawford and Edwards (1978).

Results and Discussion

Birds

122. Waterfowl, shorebirds, and perching birds comprised 55 percent of the 65 species observed during the 1975 3-month baseline study. The highest numbers of individuals and species were seen in April. Mean diversity was highest in the cottonwood-alder community and lowest in the grassland, with willow-alder, marsh-mudflat, and sand spit values intermediate. The ranking of average number of species per habitat closely matched that of mean diversity. Six species of birds nested on Miller Sands in 1975: the mallard (*Anas platyrhynchos*), Canada goose, killdeer, song sparrow, white-crowned sparrow, and common crow.

123. During the experimental period of 1976-1977, 108 bird species were seen, of which 84 percent were waterfowl, shorebirds, and perching birds. In the 107-km-long portion of the Columbia River (which included Miller Sands) studied in 1974 and 1975 by Oregon State University (U. S. Army Engineer Division, North Pacific 1976a), 125 species were seen. Waterfowl, shorebirds, and perching birds comprised 81 percent of this total. There were 84 species in common to these two listings, suggesting that the Miller Sands avifauna is representative of other areas in the lower portion of the river. A list of birds seen on Miller Sands is given in Crawford and Edwards (1978).

124. Bird use of the planted marsh was low during the first growing season, but increased with time. Numbers of shorebird species present increased, particularly during the last months of the study, to levels observed in natural intertidal habitats on Miller Sands. A larger increase in number of species observed during the second growing season occurred in the planted intertidal areas than any other habitat sampled; average per month ranged from 6.4 during July 1976 to March 1977 to 12.0 from April to August 1977. Diversity and density also increased during that period. No bird nesting was observed in any intertidal area.

125. Trends in bird density, number of species, and diversity were similar in all three planted upland areas. Density was much higher in July and August 1977 in the upland meadow planted to alta fescue/tall wheatgrass/white clover than in the other planted upland meadows, because of high numbers of swallows. Canada and snow geese fed in the meadow planted to barley/bentgrass/red clover in preference to the other two meadows. Four mallard nests were found in the meadows in 1977, two in alta fescue/tall wheatgrass/white clover and two in reed canarygrass/red fescue/hairy vetch.

126. Upland plantings appeared to cause an increase in the number of bird species in the adjacent natural meadow. Density of most species did not differ between the two areas, but the common crow was more abundant near and in the plantings. The planted meadows were used by geese more than the natural meadows. Crows, mallards, starlings (*Sturnus vulgaris*), and Savannah sparrows (*Passerculus sandwichensis*) were the most common species seen.

127. Common crows nested on Miller Sands in higher numbers than any other species, accounting for 67 inactive nests in 1976 and 39 inactive and 22 active nests in 1977. Other species with one to three nests were the willow flycatcher (*Empidonax traillii*), robin (*Turdus migratorius*), white-crowned sparrow, song sparrow, Bewick's wren (*Thryomanes bewickii*), Swainson's thrush (*Catharus ustulatus*), and Savannah sparrow. Mallards had nine nests in 1977, four in the planted meadows and five in the natural tree-shrub habitat. Islands in the Columbia River are extremely important to waterfowl nesting, since they usually lack

land-based predators (U. S. Army Corps of Engineers, North Pacific Division 1976a). However, on Miller Sands, common crows were a detriment to mallard nesting, destroying three nests.

128. Comparison of natural tree-shrub, meadow, marsh, and sand spit habitats indicates that the tree-shrub habitat was highest in bird density and diversity and the marsh habitat highest in number of bird species. Meadow habitat ranked lowest in all three characteristics. Diversity was highest in tree-shrub areas because the densities were relatively even among the species present. Flocks of several species were more common in the other habitats, resulting in uneven densities and lower diversities. These observations agree with those of other researchers who have shown that bird density and diversity generally increase with increasing complexity of the associated vegetation (Johnston and Odum 1956, MacArthur 1964, Shugart and James 1973).

129. Overall bird diversity on Miller Sands was lower than that reported for other locations in the United States (Karr 1968, Anderson 1970, Emlen 1972), whereas density was similar (Kendeigh 1944, Anderson 1970, Emlen 1972). The young ecological age of the site probably accounted for the low diversity. High densities may be related to Miller Sands being an island (MacArthur et al. 1972) or having such a high heterogeneity in vegetation associations. Crawford and Edwards (1978) provide further information concerning habitat relationships of the site.

Mammals

130. Six species of mammals were recorded from Miller Sands in the spring of 1975 (Woodward-Clyde Consultants 1978). Four Norway rats, six Townsend's voles, three Trowbridge's shrews (*Sorex trowbridgii*), and one deer mouse (*Peromyscus maniculatus*) were captured in 1544 trap-nights. Most of the captures were along the edge of the island where driftwood accumulated. Nutria and harbor seals were observed as residents and visitors, respectively.

131. Sampling after June 1976 with both snap- and live-traps yielded 14 Townsend's voles and 1 vagrant shrew (*Sorex vagrans*) in the meadow planted with reed canarygrass/red fescue/hairy vetch, and 3 vagrant shrews in the meadow of barley/Oregon bentgrass/red clover; all

the voles were caught in a patch of Scot's broom. Inventory trapping resulted in the capture of 25 Townsend's voles, 20 Norway rats, and 9 vagrant shrews. Total trap-nights of 7328 yielded 72 animals, which was the same percentage of success (0.9) recorded in the baseline study. Two-thirds of the captures were between April and August 1977.

132. Additional Norway rats, nutria, muskrats, harbor seals, and sea lions (*Zalophus californianus* or *Eumetopias jubata*) were seen. Norway rats probably had a negative effect on bird nesting success since they were present in such high numbers and are known nest predators. In addition to 20 Norway rats reported in Crawford and Edwards (1978), the professional trapper caught at least 125. By the end of December 1976, 725 nutria had been trapped and killed, which greatly decreased grazing pressure on the island's vegetation; an additional 49 were removed by 1 September 1977. During the study, 729 nutria were live-trapped on other islands. This section of the river was also reported to have high nutria populations in 1974-75 (U. S. Army Engineer Division, North Pacific 1976b).

133. The low percentage of small mammal trapping success, low number of species observed, differences in small mammal species composition during the baseline and experimental periods, and imbalance of mammal densities indicated that Miller Sands has a restricted mammal fauna, most likely due to the isolation of the island. The nearest land is about 2 km to the north across the Columbia River navigation channel. Emergent land on the south is a distance of 6-8 km. Most small mammals probably reached the island by rafting, making establishment of a viable population largely a matter of chance. Norway rats may have rafted, swam, or been introduced through man's activities; muskrats, nutria, harbor seals, and sea lions undoubtedly swam to the island. The 9 mammalian species observed on Miller Sands comprised only 25 percent of the 36 species one could expect to see on the mainland adjacent to Miller Sands (U. S. Army Engineer Division, North Pacific 1976b).

Invertebrates

134. Terrestrial arthropod biomass was extremely low in all habitats sampled on Miller Sands. A small decrease in biomass resulted from

the intertidal plantings. In upland areas, biomass decreased in conjunction with site preparation and seeding activities, but increased by July 1977 to a level slightly lower than in the grassland adjacent to the plantings.

Summary and Conclusions

135. A 3-month baseline and 14-month postpropagation wildlife study was conducted at Miller Sands. Vegetation establishment appeared to have some effect on animal distributions. In the area of the marsh plantings, bird use increased and bird species composition changed over time to include more shorebirds than were initially present. On the upland area, plantings were used by geese for food, mallards for nesting, and small mammals for cover. Small mammals apparently favored the reed canarygrass/red fescue/hairy vetch combination. Trends in bird density, number of species, and diversity were similar in all three planted meadows, although geese preferred the barley/Oregon bentgrass/red clover mixture for feeding. The plantings apparently increased the number of bird species in adjacent grassland areas. Bird nesting on the island was predominantly by common crows, which destroyed some mallard nests. Bird fauna overall is not unlike that elsewhere along the Columbia River.

136. At least 145 Norway rats and 774 nutria were collected and removed by trapping. With the exception of these, mammal populations on Miller Sands were low and were represented by a total of nine species; four of the mammal species were semi-aquatic and not restricted to living on the island.

137. Animal species composition on Miller Sands will generally change as the plant community changes, but the island location will limit access of many mammalian species. Nutria control was necessary for successful habitat development.

PART VIII: OVERALL CONCLUSIONS AND RECOMMENDATIONS

138. Plant propagation on coarse-grained dredged material at Miller Sands was generally successful in both the intertidal and upland areas. Planted areas were fairly well established by August 1977 and the plants were beginning to invade many bare, unplanted areas. Plant development in the marsh areas is expected to continue and expand in the following years. Sustained plant development in the upland meadows, however, is unlikely without periodic maintenance.

139. Animal response to the planted areas primarily reflected the early stages of succession during which the animal populations were sampled. In general, plantings did not noticeably affect animal diversity or number of species observed. However, avian species composition changed in the intertidal areas from those species preferring bare, sandy areas to those preferring vegetated areas. An increase in small mammal abundance was also noted in the planted upland areas. A brief description of some of the more salient conclusions and recommendations developed from the Miller Sands study is provided below.

- a. Periodic disposal of dredged material was necessary to avoid loss of material by erosion on the channel side of the sand spit. The spit provided an effective barrier from ship wakes and, therefore, continued maintenance of the sand spit by routine channel dredging and careful placement of dredged material is recommended.
- b. Establishment of tufted hairgrass and slough sedge in the monotypic plots was successful only at intertidal elevations greater than 67 cm above MLLW when sprigs were used as transplants. No positive results were obtained from planting seeds. Fertilizer application had no significant effect on the successful establishment or on the production rates of slough sedge.
- c. After one year's growth, tufted hairgrass sprigs approached values derived from nearby native stands. Natural establishment of vegetation on originally bare areas adjacent to the marsh planting site and natural marsh was generally insignificant and, for the most part, restricted to areas protected from current and wave energies.
- d. Intertidal mixed plantings developed from transplants of Lyngby's sedge, American bulrush, common rush, yellow flag, and water plantain were successful, demonstrating

their potential for use in similar habitats. No positive results were obtained from seeds for any of the species tested in the mixed plantings.

- e. European beachgrass cuttings planted on the sand spit in January and May 1977 successfully reduced the amount of windblown sand initially carried into the planted intertidal areas. Application of fertilizer did not significantly affect growth of either the January or May plantings.
- f. The feasibility of planting selected legumes and grasses by seeding within the upland meadows was demonstrated during this study. However, the future success of these plantings remains uncertain. Native plants may outcompete the legume and grass plantings within several years unless the planted species are periodically reseeded and fertilized.
- g. Alternative approaches to increasing the productivity of the sandy upland dredged material should be considered. One approach should include adding one or more layers of "nutrient-rich" dredged material to the surface of the existing substrate. Such an approach has the potential of being less expensive and more predictable as an upland habitat development approach where coarse-grained dredged material substrates are involved.
- h. The development of plants in the intertidal area was successful but the plantings seemed to have no detectable influence on the aquatic biota. Fish distribution was uniform throughout the cove and intertidal areas before and after habitat development. This distribution pattern is partly a result of the early successional stage of marsh development and partly a result of tidal hydraulics which forces fish out of intertidal areas during a falling tide. However, detection of differences in distribution was restricted because of fish sampling methods and large variability in the catch. Fish sampling techniques in shallow vegetated habitats are not satisfactory at the present time to detect subtle differences between the various habitats sampled. Therefore, future efforts should be directed toward improving fish collection techniques. Studies conducted before, during, and after habitat development indicated that fish abundance was similar for all three phases of site development activities.
- i. The benthic community at the field site exhibited seasonal trends in abundance and species composition and, like the fish community, was fairly evenly distributed throughout the habitat. Benthic studies conducted before and after habitat development indicated that the marsh

developed by July 1977 had little influence on the benthic community.

- j. The fish food habit study indicated that 96 percent of the items consumed were composed of only five types of organisms; the two most abundant organisms were zoo-plankton. Therefore, these important food items should be examined at the field site to assess long-term habitat development influence on this component of the aquatic community.
- k. Bird use of the planted intertidal areas slowly increased as development of the marsh progressed, although use was generally less than at the intertidal reference areas. Few mammals were collected in the intertidal areas before or after plant propagation.
- l. Waterfowl used the planted upland meadows more than the natural grassland area with mallards using the planted area for nesting and Canada geese using it for food and cover. If future planted habitats are developed as nesting areas for waterfowl, a program should be undertaken to reduce predation from crows and Norway rats, as these two animals are very damaging to nesting success.

LITERATURE CITED

- Anderson, S. H. 1970. The avifaunal composition of Oregon white oak stands. *Condor* 72(4):417-423.
- Bond, R. R. 1957. Ecological distribution of breeding birds in the upland forests of southern Wisconsin. *Ecol. Monogr.* 27(4):351-384.
- Boyd, M. B., R. T. Saucier, J. W. Keeley, R. L. Montgomery, R. D. Brown, D. B. Mathis, and C. J. Guice. 1972. Disposal of dredge spoil: problem identification and assessment and research program development. TR H-72-8. U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
- Carlander, K. D. 1969. Handbook of freshwater fishery biology. Vol. One: Life history data on freshwater fishes of the United States and Canada, exclusive of the Perciformes. The Iowa State University Press. Ames, Iowa. 752 pp.
- Clemens, W. A., and G. V. Wilby. 1961. Fishes of the Pacific Coast of Canada. Fisheries Research Board of Canada, Ottawa, Canada. Bull. No. 68.
- Crawford, J., and D. Edwards. 1978. Habitat development field investigations, Miller Sands marsh and upland habitat development site, Columbia River, Oregon, Appendix F: postpropagation assessment of wildlife resources on dredged material. TR D-77-38, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
- Cutshall, N., and V. G. Johnson. 1977. Habitat development field investigations, Miller Sands marsh and upland habitat development site, Columbia River, Oregon, Appendix A: inventory and assessment of predisposal physical and chemical conditions. TR D-77-38, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
- Eddy, S. 1969. The freshwater fishes. Wm. C. Brown Co., Dubuque, Iowa. 2nd Ed. 286 pp.
- Emlen, J. T. Jr. 1972. Size and structure of a wintering avian community in southern Texas. *Ecology*. 53(2):317-329.
- Hart, J. L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Ottawa, Canada. Bull. No. 180. 740 pp.
- Heilman, P. E., D. M. Greer, S. E. Brauen, A. S. Baker. 1978. Habitat development field investigations, Miller Sands marsh and upland habitat development site, Columbia River, Oregon. Appendix E: postpropagation assessment of botanical and soil resources on dredged material. TR D-77-38, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

- Higley, D. L., and R. L. Holton. 1975. Biological baseline data: Youngs Bay, Oregon. 1974. Final report to ALUMAX Pacific Aluminum Corporation, 1 November 1973 through 30 April 1975. School of Oceanography Reference 75-6. Oregon State University, Corvallis, Oregon. 91 pp.
- Higley, D. L., R. L. Holton, and P. D. Komar. 1976. Analysis of benthic infauna communities and sedimentation patterns of a proposed fill site and nearby regions in the Columbia River estuary. Final Report to Port of Astoria, Astoria, Oregon, 1 November 1975 through 29 February 1976. School of Oceanography Reference 76-3, Oregon State University, Corvallis, Oregon. 788 pp.
- Johnston, D. W., and E. P. Odum. 1956. Breeding bird populations in relation to plant succession on the Piedmont of Georgia. *Ecology*. 37(617):50-62.
- Lunz, J. D., T. W. Zeigler, R. T. Huffman, R. J. Diaz, E. J. Clairain, and L. J. Hunt. 1978. Habitat development field investigations, Windmill Point marsh development site, James River, Virginia; Summary report. TR D-77-23, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
- Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. *Condor* 70(4):348-357.
- Kendeigh, S. C. 1944. Measurement of bird populations. *Ecol. Monogr.* 53(2):278-272.
- MacArthur, R. H. 1964. Environmental factors affecting bird species diversity. *Amer. Natur.* 98(903):387-397.
- MacArthur, R. H., J. M. Diamond, and J. R. Karr. 1972. Density compensation on island faunas. *Ecology*. 53(2):330-342.
- Maguire, J. D., and G. A. Heuterman. 1978. Influence of pregermination conditions on the viability of selected marsh plants. TR D-78-51, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
- McConnell, R. J., S. J. Lipovsky, D. A. Misitano, D. R. Craddock, and J. R. Hughes. 1978. Habitat development field investigations, Miller Sands marsh and upland habitat development site, Columbia River, Oregon, Appendix B: inventory and assessment of predisposal and postdisposal aquatic habitats, TR D-77-38, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
- National Oceanic and Atmospheric Administration. 1976. Local climatological data, Astoria, Oregon. National Climatic Center. Asheville, North Carolina.

- Sanborn, H. R. 1975. Benthic infauna observed at five sites in the Columbia River from August 1973 to July 1974. National Marine Fisheries Service, Completion Report to the U. S. Army Corps of Engineers and Columbia River Programs Office. Portland, Oregon.
- Shannon, C., and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press, Chicago. 117 pp.
- Shugart, W. J., Jr., and D. James. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. AUK 90(1):62-77.
- Ternyik, W. E. 1978. Habitat development field investigations, Miller Sands marsh and upland habitat development site, Columbia River, Oregon, Appendix D: propagation of vascular plants on dredged material. TR D-77-38. U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
- U. S. Army Engineer District, Portland. 1975. Final environmental impact statement: Columbia and lower Willamette River, maintenance and completion of the 40-foot navigational channel downstream of Vancouver, Washington, and Portland, Oregon.
- U. S. Army Engineer Division, North Pacific. 1976a. Inventory of riparian habitats and associated wildlife along Columbia and Snake Rivers. Vol. I. 100 pp.
- U. S. Army Engineer Division, North Pacific. 1976b. Inventory of riparian habitats and associated wildlife along Columbia and Snake Rivers. Vol. IIA. 861 pp.
- U. S. Army, Office, Chief of Engineers. 1969. 1968 annual report of the Chief of Engineers on civil works activities. Washington, D. C.
- Woodward-Clyde Consultants. 1978. Habitat development field investigations, Miller Sands marsh and upland habitat development site, Columbia River, Oregon, Appendix C: inventory and assessment of prepropagation terrestrial resources on dredged material. TR D-77-38. U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Table 1

Project Costs for Habitat Development at
Miller Sands, Columbia River, Oregon

Cost Category	Approximate Unit Cost*	Total
I. Construction and Maintenance Cost		
A. Dredging operations		
1. 1974	\$0.6209/m ³	\$ 380,034
2. 1975	\$0.7045/m ³	166,798
3. 1976	\$0.3666/m ³	52,790
4. 1977	\$0.7279/m ³	58,959
B. Subsurface exploration and profiles		6,000
C. Grading and plot layout		11,000
D. Elevation surveys		4,500
E. Contracted plant propagation		87,912
Subtotal		\$ 767,993
II. Research Cost		
A. Preparation of work statements, Miller Sands Island, Columbia River		\$ 1,243
B. Baseline biological inventory and assessment of the aquatic environs of the Miller Sands Habitat Development Site		38,500
C. Inventory and assessment of existing environmental conditions at Miller Sands Island in the lower Columbia River, Oregon - terrestrial fauna and flora		38,926
D. Inventory and assessment of existing environmental conditions at Miller Sands Island in the lower Columbia River, Oregon - physical and chemical		52,689

* Figures obtained from Mr. Mel Maki, Navigation Branch, U. S. Army Engineer District, Portland, on 24 April 1978 were provided as cost/yd³ and converted to appropriate metric values.

(Continued)

Table 1 (Concluded)

Cost Category	Approximate Unit Cost	Total
E. Pilot study of propagation of marsh plants at Miller Sands Island in the lower Columbia River, Oregon		\$ 9,817
F. Trapping of nutria at Miller Sands		33,360
G. Post-propagation monitoring of wildlife resources at Miller Sands Habitat Development Site, Columbia River, Oregon		39,855
H. Aquatic biology investigation at Miller Sands Habitat Development Site, Columbia River, Oregon		80,000
I. Post-propagation monitoring of botanical and soil resources at Miller Sands, Columbia River, Oregon		167,798
J. Postoperational aquatic biology at Miller Sands Habitat Development Site		45,072
K. Portland District support other than specified under I above		<u>13,803</u>
Subtotal		\$ 521,063
Grand total		\$1,289,056

Soil Parameters for the Upland Meadows as Influenced by Meadow Number and Time of Sampling

* Values in columns not followed by the same letter are significantly different at $p = 0.05$ according to Duncan's Multiple Range Test.

Table 3

Soil Parameters for the Upland Meadows as Influenced by Fertilizer Treatment and Sampling Time

Fertilizer Treatment*	pH	K ⁺ meq/100g	P ppm	NH ₄ ⁺ -N ppm	TKN		NO ₃ ⁻ -N ppm	Moisture		Carbon percent	CEC meq/100g
					percent	percent		percent	percent		
					June 1977						
F0	5.89a**	0.163a	5.73b	0.717a	0.0141b	0.575b	0.717a	7.54a	--	--	--
F1	5.86a	0.174ab	6.46b	0.896a	0.0154ab	0.713a	0.713a	7.35a	--	--	--
F2	5.82a	0.188b	7.67a	0.913a	0.0168a	0.658ab	0.658ab	8.97a	--	--	--
					August 1977						
F0	6.18a	0.150a	6.50b	1.175b	0.0133b	0.718a	0.718a	18.99a	0.200b	3.92a	3.92a
F1	5.98b	0.162a	7.94a	1.751a	0.158a	0.784a	0.784a	17.04ab	0.252a	3.98a	3.98a
F2	5.84c	0.163a	8.35a	1.629a	0.159a	0.826a	0.826a	16.31b	0.243a	3.97a	3.97a

* F0 = no fertilizer

F1 = 224 kg/ha of 10-10-10 in fall plus

224 kg/ha of 10-10-10 in spring

F2 = 448 kg/ha of 10-10-10 in fall plus

448 kg/ha of 10-10-10 in spring

** Values in columns not followed by the same letter are significantly different at p = 0.05 according to Duncan's Multiple Range Test.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Clairain, Ellis J

Habitat development field investigations, Miller Sands marsh and upland habitat development site, Columbia River, Oregon; summary report / by Ellis J. Clairain, Jr. ... [et al.]. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

72, [4] p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-77-38)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under DMRP Work Unit No. 4B05M.

Appendices A-D on microfiche in pocket.

Appendices E and F published separately.

Literature cited: p. 70-72.

1. Columbia River. 2. Dredged material. 3. Field investigations. 4. Fishes. 5. Habitat development. 6. Habitats. 7. Marsh development. 8. Miller Sands Island. 9. Vascular plants. 10. Vegetation establishment. 11. Waste disposal sites. 12. Wildlife. I. United States. Army. Corps of Engineers. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-77-38.

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